



Addressing Our Global Water Future

Center for Strategic and International Studies (CSIS)
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EXECUTIVE SUMMARY

This White Paper addresses the growing global challenges of dealing with the devastating effects of increasing water scarcity and declining water quality. Across the planet, in developing and developed regions alike, poor governance and mismanagement of natural resources coupled with rising population growth, increasing urbanization, and economic development have led to a growing imbalance between water supply and demand. This imbalance is reaching crisis proportions in many regions. It will have even more significant consequences for economic development, stability and security unless there is a more dramatic and urgent international response. Several international forums have arisen to address just this issue. The question remains how the United States could and should engage these forums and formulate a response to the world's freshwater challenges. The goals of this White Paper, therefore, are to (1) make the case for elevating the response to global water challenges as a strategic priority; (2) identify the most effective responses to global water challenges; and (3) explore U.S. policy options, current and future.

From previous experiences across the planet, it is clear that institutional capacities in governance systems across the world (varied as they are) must all be strengthened to adequately address the magnitude of future challenges involving water. Improving governance will enable and facilitate the development of strategies and responses engaging the full range of available water-related technologies—from high-tech, high expense to low-tech, low expense. Solutions across that range exist today and must be deployed at new and greater scales in order to reduce the impacts on public health, economic development, environmental degradation, and political stability. Continual effort and investment is needed to develop as-yet-unknown technologies, policy approaches and synergies that could jumpstart new solutions in the decades to come. Policy and technology must evolve together to effectively link innovative strategies with innovative technologies. For these reasons, this White Paper emphasizes the development of strategies to address current and future global water challenges with a specific focus on governance and technology and the critical linkages between the two.

This paper is organized in four parts to explore the three goals outlined above. Section One describes the nature and scope of the global water challenges that face the world. Sections Two and Three explore potential areas for innovation and synergy in policy, governance, capacity building, and the application of technologies. The paper culminates in Part Four with an examination of how the United States should integrate water into its foreign policy.

This Executive Summary highlights the analysis in the White Paper by pointing to 14 specific findings, organized by four broad themes, that emerged from extensive background research and two major workshops sponsored by CSIS and Sandia

National Laboratories in February and March 2005. Detailed support of the assertions and recommendation made in this Executive Summary are set out in the text of the full paper.

A more detailed description of the overall CSIS-Sandia effort, including multimedia materials from our two workshops, can be found at <http://gsi.csis.org/waterweb/index.html>.

THEME ONE:

Already at crisis proportions, global water problems could be a source of conflict and instability in the future.

Finding 1: Water scarcity caused by mismanagement and a growing imbalance between supply and demand is driving us toward a tipping point in human history. *Global trends of increasing population, increasing natural resource consumption, and decreasing natural resource availability—including freshwater—have pushed many human social, economic and political systems to an important tipping point. Poor management of natural resources exacerbates the problem. We face large-scale future dislocations and crises unless significant action is taken now by leaders in both developed and developing countries.*

Increasing human population and continued economic development leading to increasing consumption and decreasing availability of many natural resources have set the world on a collision course with global physical and ecological constraints. Poor management of resources hastens the potential for this collision. Humans already appropriate over half of all accessible freshwater resources, and future water withdrawals and consumption are expected to continue their steady rise. By 2025, over half the world's population will live in water stressed or water scarce countries.

These issues are driven by trends in population growth, urbanization, industrialization, economic development, and climate change. More people will need to be fed by dwindling sources of arable land. Rising food demand will push the expansion of irrigated agriculture—already one of the most inefficient uses of water. Likewise, economic development requires new power plants that use significant amounts of water in cooling towers. Industrialization will also continue to attract water-intensive industries to water-stressed developing countries—China serving as a case in point.

The consequences of over-consumption and mismanagement on human health, economic development and the functioning of regional and global aquatic ecosystems are already dire and can be expected to worsen. Groundwater levels are

dropping and rivers, lakes and wetlands are drying up around the world. Billions of people already lack access to safe drinking water or basic sanitation facilities. Water pollution further constrains safe water supplies for people, agriculture, industry, and ecosystems.

In addition, the reach of these challenges is expanding. They apply not only to arid regions and developing nations but also to developed countries. Almost every region of the world is already experiencing—or soon will experience—water shortages and/or water quality challenges. Coordinated and consolidated regional and global efforts will be necessary to accelerate progress and to keep step with the array of forces affecting global water supply and demand.

Finding 2: Water is a foundation for human prosperity. *Adequate, high-quality water supplies provide a basis for the growth and development of human social, economic, cultural and political systems. Conversely, economic stagnation and political instability will persist or worsen in those regions where the quality and reliability of water supplies remain uncertain.*

Adequate supplies of freshwater are a cornerstone for human activities at all scales, from daily subsistence needs to higher levels of economic production. Lack of access to safe, clean water for drinking, sanitation, agriculture, or industry is perpetuating cycles of poverty and limiting viable development options in regions around the world.

Without access to a reliable and convenient source of water, family members, most often women and girls, can spend hours each day collecting water. In addition, the water supply is typically unsafe or is stored and transported in ways that ultimately contaminate it. Either situation can result in contraction of life-threatening water-related diseases. Water-related diseases and the requirements of water collection keep children from attending school and keep adults from engaging in productive economic activities. The costs of lost productivity and foregone economic opportunity can be measured in the hundreds of millions of dollars, even in areas of the world where wages may be only a few dollars a day. These concerns are equally relevant for both urban slums and remote rural areas, but the solutions for addressing these challenges differ with each situation.

On a broader scale, countries require a certain level of water infrastructure to support economic activities. Irrigation networks overcome drought and prevent famine; dams and dikes regulate water flows and avoid floods. Countries with adequate infrastructure and institutions to balance low flows and high flows across geographic and temporal barriers are able to protect water quality and capitalize on the productive benefits of water while minimizing the risks of too much or too little water at any given time. For these countries, water represents a net positive force for the economy. In contrast, for countries susceptible to variations in water flow or

unable to ensure its quality, water represents a significant barrier to economic growth. Not only can water hamper economically productive activities, but it also may deter risk adverse investors both within the country and from abroad.

Ecosystem degradation caused by water withdrawals, loss of wetlands, and water pollution will also hinder economic development by affecting ecosystem services—purification and delivery of fresh water, decomposition of wastes, generation of soils, pollination of crops, production of wood and fiber, etc.□

Finding 3: Water problems are geopolitically destabilizing. *Water scarcity and poor water quality have the potential to destabilize isolated regions within countries, whole countries, or entire regions sharing limited sources of water. There is an increasing likelihood of social strife and even armed conflict resulting from the pressures of water scarcity and mismanagement.*

Water scarcity and poor water quality could lead to increased potential for domestic instability and heightened transnational tensions. History shows that in many regions around the world, water has been a source of considerable cooperation between nations sharing water resources. However, increasing populations and water scarcities may bring about a different future. In the years ahead, instability or conflict related to water supplies will likely take two forms: (1) domestic unrest caused by the inability of governments to meet the food, industrial, and municipal needs of its citizens, and (2) hostility between two or more countries—or regions within a country—possibly leading to greater insecurity or conflict, caused by one party disrupting the water supply of another.

Over the past five years, several domestic upheavals involving water have erupted across the world. These violent episodes have occurred in countries with varying degrees of economic development and in both rural and urban settings. However, they were all largely the results of the perception or reality of rising imbalances in water availability and the failures of governments to effectively and transparently mediate the concerns and demands of various users.

Growing water imbalances will also alter international relationships. Changing patterns of food trade caused by water scarcity will influence international alliances. Cross-border relations between riparian countries in water stressed regions will undoubtedly be shaped by water sharing agreements or the lack thereof. Conflicts related to water scarcity will continue to strike hardest in regions already facing geopolitical stress and conflict and will exert enormous pressure on existing transboundary and domestic instabilities.

□

Finding 4: Poor governance and poor economies contribute to and exacerbate water scarcity problems. *Poor governance and poor economies in regions around the world where water challenges are most severe impair the effective application of either innovative technology or innovative policy. Furthermore, poor governance creates a disincentive to the mobilization of international and domestic financial resources. Solutions to water problems must therefore be linked to improvements in governance.*

There is a general deficit in good governance, strong institutions, adequate financial investment, and political will. These factors are as much a cause of global water imbalances as trends in population growth and economic development—and these shortcomings are cause for more immediate concern.

Specific water governance concerns differ across all nations but can be grouped into three broad categories: (1) institutional and regulatory environments, (2) the tensions between central and periphery management, and (3) governance capacity.

Insufficient or poorly defined regulatory environments create confusion about roles and responsibilities for citizens, government institutions, and the private sector. In addition, a lack of firm regulations and the institutional capacity to enforce those regulations often translates into a lack of incentives for water utilities, whether publicly or privately managed, to expand infrastructure to the poor and maintain water quality.

Increasing local participation in the planning, implementation, and maintenance of water projects would improve sustainability by shoring up regulatory oversight, incorporating local knowledge, better addressing local needs, and creating community buy-in. However, low levels of education, sharp societal divides, bureaucratic impediments, and possible corruption at all levels of governance act as obstacles for civil society to take on the roles that would make decentralized approaches effective. Capacity building across the board in technical, financial, managerial, and social intermediation is necessary.

An absence of incentives and poor governance can also lead to severe gaps in available capital for expanding, maintaining, and improving water infrastructure. Current estimates suggest annual investment in water infrastructure will need to double over the next two decades. Sources of capital for infrastructure development in developing countries have traditionally come from predominantly domestic sources rather than foreign assistance. If official development assistance and private sector spending on infrastructure continues to decline in the future, governments will have to expand their share of infrastructure investment. Poor governance will continue to create obstacles for raising the necessary financing. □

THEME TWO:
Institutional capacities must transform and expand in many ways to meet current and future challenges.

Finding 5: Solutions must be innovative, revolutionary, and self-sustaining. *Current trajectories for improvement in freshwater availability and quality are inadequate to meet global needs in a timely way. Innovative solutions must be found and employed that replace steady, incremental rates of progress with dramatic, revolutionary changes. These solutions must be designed to be self-sustaining over the long-term.*

Current efforts are inadequate to meet near-term, large-scale crises in strategically important regions of the developing world. These efforts will also fall short of meeting longer-term, large-scale shortfalls in developed regions. In order to meet targets and to make efforts sustainable, the world community must adopt thinking and strategies that do not simply provide “more of the same,” but that actually change the trajectory of current progress. Efforts must yield exponential progress—or “step changes”—rather than linear progress. These new trajectories must be pursued through new policy approaches, new technologies, and new synergies between the two.

Sustainable solutions generally exhibit three characteristics. First, they are strategic. Water is a strategic resource, meaning it is vitally important to human prosperity, economic development, environmental health, and political and geopolitical stability. The most effective solutions will recognize this importance and leverage the different roles water plays in each of these areas. Second, sustainable solutions are innovative. Innovation can stem from not only entirely new solutions, but also new applications and new mixes of past solutions. Finally, sustainable solutions are effective over the long-term. Long-term solutions not only extend the lifespan of solutions implemented today, but also leverage the next generations of innovations and successes in an ever-rising upward spiral. Strategic, innovative, long-term approaches will be necessary to solve the global water challenges of both today and tomorrow.

Finding 6: Participatory principles strengthen sustainable solutions. *Effective water planning and management at local and regional levels requires a broad and integrated collaboration, including farmers, urban developers, environmentalists, industrialists, policy makers, citizens, and others, all within an open and participatory framework. Water improvement and management projects conducted at local and regional levels that promote the principles of multi-stakeholder processes and open communication can play a dual role as democracy-building projects.*

The foundation for any self-sustaining strategy that addresses water challenges is an open, participatory system that engages all relevant stakeholders—farmers, urban developers, environmentalists, civil society, nongovernmental organizations, local to national government representatives, and others. This approach must strike a balance between economic, social and environmental interests.

The concept of “integrated water resource management” (IWRM) is heralded as a means to overcome the traditional sectoral treatment of water. IWRM seeks to give consideration to the multiple uses of the resources. IWRM strategies must consider both the physical dimensions of a source of water—location, type, quantity, and quality—as well as the nonphysical—the interests, habits, education levels, cultural predilections, preferences and objectives of the broad array of water users, as well as broader ecological, political and economic goals imposed by society. A framework to move towards effective IWRM must ensure the concurrent development and strengthening of three elements: (1) an enabling political and regulatory environment; (2) appropriate institutional roles for all stakeholders; and (3) practical management tools and approaches drawn from policy, technology and economics and appropriate for the circumstances in which they are applied.

Effective integrated water resource management relies upon community participation. The principles of this approach can be applied at any level and at any scale, depending on the circumstances. As such, participatory, integrated water projects can improve gender equality, foster democratic institutions, and improve tenuous or uncertain cross-border relations.

□

Finding 7: Sustainable strategies must include diverse and multi-institutional partnerships. *No single government agency, non-governmental organization, corporation, international organization, or academic institution can provide all the required expertise or coordinate a sufficiently integrated response to meet the nature and scope of the challenge we face. Partnerships across social organizations are necessary for both developing and implementing sustainable solutions.*

The varying competencies of government agencies, international organizations, non-governmental organizations, the private sector, and academic institutions can all provide specific expertise to addressing water challenges in situations across the globe; but no single organization can effectively address these challenges without the support and cooperation of the others. In both donor governments and recipient governments, agencies from federal to local levels have specialized knowledge that will deliver optimal solutions only when resources are pooled and collaboration is enhanced. The private sector has increasingly become engaged in issues related to freshwater, lending both expertise and financial resources. Greater coordination and cooperation between the private sector, nongovernmental organizations, governments, international organizations, and academic institutions both within countries and across borders will foster truly innovative and sustainable solutions. Greater cross-sector collaboration must occur to foster more effective resource planning and implementation.

Finding 8: New ways of investing in, pricing and valuing water can provide powerful solutions. *A serious funding gap exists between projected financial needs and current trends in spending on water projects. International lending institutions and official development assistance should be leveraged to generate more in-country capital. Private-sector involvement offers a largely untapped source of investment, leadership, knowledge, and innovation, and must be mobilized. Difficulties in valuation of water and inadequate economic indicators obfuscate the role sustainable water resources play in economies. A participatory governance structure, strong institutions, clear regulatory frameworks, and better valuation methods will all support the development of new, innovative modes for financing improvements and expansion of water infrastructure.*

While official development assistance (ODA) for water projects has been declining, ODA constitutes only a small fraction of total spending on water services. Therefore, to effectively address the growing gap between current and still needed investment, new, innovative methods of financing must be made available to governments in developing countries. Creative approaches to finance include municipal bond issuance, public-private partnerships, revolving fund models, and the creation of enterprise development funds focused on water issues.

Expanding investment will help alleviate many of the world's water challenges, but long-term sustainability is contingent on formulating robust water pricing models. New pricing structures based on cost-recovery will be key not only in providing the necessary incentives for investors to make a commitment to water projects, but also to provide the revenue necessary for operation and maintenance of existing systems. Such pricing models will also be necessary to engage the private sector, and in turn reap the benefits of greater efficiencies and improvements in service often realized through privatization.

However, the potential for marginalization of the poor and important cultural values must be recognized. Creating a strong regulatory framework integrated with an open, participatory management structure will support systems in which water prices can be readjusted to better reflect the cost of delivery, and in which the interests of both the water providers and the poorest segments of society are met.

□

THEME THREE:

Policy approaches and technological approaches must be fully integrated.

Finding 9: Innovations in policy and technology must be tightly linked. *Innovations in policy can lead to important developments in technology, and,*

likewise, innovations in technology can lead to important developments in policy. Institutions must realize the synergies made possible by integrating policy and technology.

A wide gap exists between technology and policymaking at the local, regional and global levels. To bridge this gap, greater communication between those people who set the policies, develop new technologies and implement new solutions must be applied. There is a corresponding need for greater cross-fertilization of ideas and approaches and more integrated planning. Shifts in policy approaches that include new strategies, new funding, new regulations, or new educational campaigns will all benefit from understandings of current and future technologies. Effective and sustainable research, development and implementation of new technologies depend upon policy frameworks informed by current and future technological capabilities. In the case of monitoring and modeling capabilities, for example, technology can be used to directly inform policy and frame water management plans. In order to reach the economies of scale necessary for effectively addressing global water challenges, innovative solutions through the coordination of policy and technology will be necessary. □

Finding 10. Solutions must be specifically tailored to the socioeconomic, political and geographic conditions of a region. *Solutions to water scarcity and water quality problems are different for different regions and for different socioeconomic and demographic groups within regions. Solutions must therefore be designed to meet the specific kinds of challenges presented by different socioeconomic, climatic, geographic and geopolitical conditions.*

There is no “silver bullet” for addressing global water scarcity or water quality issues. No two sets of tools, approaches or strategies applied to specific regions will look the same. Strategies must be differentiated to account for a number of factors, including level of economic development, governance structure, cultural attitudes toward water and water utilities, education levels, communication capabilities, the physical environment, and other factors. These factors can and do change from country to country, but also within countries, so that it may not be possible or effective to simply scale up locally successful programs to the national or international level.

The technological scale for expanding water supply spans new village wells and treadle pumps at one end to desalination plants and large-scale infrastructure such as dams at the other. The scale for improving water treatment spans point-of-use household treatment procedures to citywide treatment facilities. Many technological solutions exist for reducing water demand through improving agricultural, industrial, and domestic efficiencies. Technology can also aid in the management of water supplies through collecting, transmitting, and interpreting data. All of these approaches must be integrated with localized and differentiated policy applications

that must contend with the governance and political will pressures examined in other sections of this paper.

Finding 11: Planning for and management of water, energy and agriculture must be strongly integrated. *Important interdependencies exist among water, agriculture and energy production, all of which are critical to human welfare and economic development. Technologies and policies focused on improving efficiencies in food production, power generation, or water use should take into consideration and leverage this interconnectedness for maximum impact.*

Agriculture uses large amounts of energy and water and is a major source of non-point source water pollution. Similarly, large quantities of water are withdrawn, consumed and sometimes impaired for energy production, while water mining and distribution networks require a great deal of energy to operate. The expected rise in global population will drive a corresponding rise in demand for food, energy, and water as well as tighten the interdependencies between the three. Such close linkages also give rise to an increasing possibility of political or economic upheavals stemming from a lack of any one of the key resources.

Many technologies exist to improve efficiencies among agriculture, energy and water—ranging from drip irrigation, to low-flow household appliances, to recycling techniques and recirculating cooling systems—but greater innovations to policy, subsidies, regulatory frameworks and other incentives are required. Further exploring the linkages, improving efficiencies, and integrating management plans among the three would serve to expand water supplies and to mitigate water demand. A full understanding of the nexus between water, energy and agriculture is vital to improving the management of all three sectors. This overarching comprehension will serve to secure global energy, food, and water supplies for a growing world, while capitalizing on innovative and sustainable solutions.

Finding 12: Robust capacity building is essential. *Results achieved around the world by existing technical aid and infrastructure development programs can be vastly improved with greater efforts to support regional capacity building. These efforts should be aimed at regional education, political and economic innovation and technical expansion sufficient for long-term operation and maintenance by local, indigenous institutions. They must also include both technical and institutional capacity-building.*

Development assistance for improving water conditions must include adequate development of the indigenous technical capacity and knowledge base. Current approaches most often use ODA or international loans to fund U.S. companies as they provide infrastructure and/or services. But these approaches do not explicitly develop the type of robust program in capacity building that could leave indigenous

populations with new infrastructure along with the enduring capability to sustain it and to even spread it throughout their region or country.

Technological or financial assistance should be coupled with providing fundamental skills and capabilities required for developing and maintaining sustainable, localized solutions over the long term. These capacities must include not only the development of physical infrastructure, but institutional capacity building—such as training and educational opportunities for regional policymakers, managers, industrialists, bankers, and others—must be pursued to support these projects. All of these efforts must be conducted with the specific needs and circumstances of the country in mind. □

THEME FOUR:

The United States should raise international water issues on its list of priorities as a way of enhancing U.S. national security.

Finding 13: Water can be a powerful and effective foreign policy tool.

Effective engagement of international water issues can significantly support many U.S. foreign strategic objectives. Strategies to address geopolitical and regional instabilities, economic development, humanitarian concerns and democracy are more likely to succeed by elevating the issue of water.

Water is a missing element for support of many U.S. strategic pursuits abroad. Enabling and supporting other countries as they establish integrated strategies for managing water supplies is important for maintaining and fostering peace and stability between and within countries. This is particularly true as trends in population and natural resource consumption continue to put pressure on economies and governance structures. Because water is so integral to every aspect of human life and activity, many strategies to promote economic development or humanitarian relief (e.g., poverty reduction or HIV/AIDS relief) cannot be achieved without pronounced attention to water. By fostering inclusive decision-making and management processes at a local scale, water projects can also strengthen democracy-building projects in areas where such projects are not well received. Water should be a key component in any short-term or long-term regional stabilization and reconstruction effort. Water scarcity, water quality, and water management could both positively and negatively impact every major U.S. strategic priority in every key region of the world.

For all of these reasons, water can no longer be regarded exclusively as a function of U.S. humanitarian and foreign assistance policies. It has significant security, political, social, economic and commercial implications for U.S. interests as well. For

this reason, there is a strong argument to be made that U.S. policymakers should elevate water on the list of enduring U.S. interests. Water has become a strategic and foundational element of U.S. international interests. □

Finding 14: An integrated, comprehensive international U.S. water policy is essential: *The United States has the technical capacity, knowledge, and wealth to help relieve water scarcity problems in countries and regions around the world. However, a lack of coordination and prioritization among all the different agencies involved in the decision making and policy implementation process has lead to a largely ad hoc approach to global water issues. The United States should therefore develop a coherent, comprehensive water strategy for meeting global water challenges in order to maximize its impact and achieve broader U.S. foreign policy objectives.*

The United States is well positioned to take the lead in addressing global water issues. The U.S. already contributes a significant amount of resources to international water issues—an estimated \$3 billion between 2000 and 2004. However, it remains unclear whether these commitments adequately reflect the absolute importance of water to overall foreign policy goals. Official Development Assistance has vacillated significantly in the past decade. The increase in funding by the Bush administration through the “Water for the Poor Initiative” and the commitment made at the World Summit on Sustainable Development are noteworthy, but represent one-time commitments without the accompanying evaluation of needs, priorities, and internal coordination necessary to adequately address the challenges. On the other hand, two attempts have been made by Congress in the past year to elevate the strategic importance of water and to improve coordination—but these risk becoming unfunded mandates.

At the operational level, nearly every federal agency or research institution has conducted an international water project. Yet each applies this expertise and experience on a limited, ad-hoc basis. Significant research and development is taking place within the United States in an effort to address our own water scarcity and water quality problems, and these efforts can be usefully applied in regions around the world. Furthermore, the majority of official development assistance for water is conducted on a bilateral basis through USAID and does not reach some of the countries with the greatest water needs. Development of an integrated and cohesive international policy on water will be a major step forward in mobilizing and coordinating the vast resources of the U.S. Government already engaged on global water issues. Such a step may also be critical to achieving many U.S. foreign policy goals.

□

CONCLUSIONS and RECOMMENDATIONS

Natural resource availability and sustainability are precursors to global economic and political stability, which, in turn, are precursors to U.S. national security interests. The findings described above offer the components for a comprehensive and ultimately sustainable approach to managing water resources at the local, regional and global levels. These findings address not only physical water scarcity and water quality issues, but also the capacity building, policy-making, economic and governance issues that are interwoven with the water challenges.

The implementation of these findings will not only help resolve water scarcity problems, but will also contribute to greater regional and global stability, improved governance, and the greater spread of democratic principles—all of which will strengthen the sustainable management of water and other resources. Water weaves together international goals for human development, economic prosperity, peace and stability, no matter what the region, what the circumstances, or what the goal.

These water challenges present important risks and opportunities for U.S. international strategic interests. Failure to act could lead toward continued economic stagnation. Failure to engage could contribute to domestic and international tensions or unrest, and it could result in further human suffering and death across the planet. Proactive, innovative, and coordinated actions by the United States, on the other hand, will advance every major strategic priority of U.S. foreign policy—most notably economic development and the building of democratic institutions and practices. Water can no longer be regarded solely as a tool or by-product of U.S. development and humanitarian programs. Instead, it should be recognized as a lynchpin for the broader international engagement strategy of the United States. Policies focused on water in regions across the planet must be regarded as a critical element in U.S. national security strategy. Such policies should be part of a broader, comprehensive, and integrated U.S. strategy toward global water challenges.

In the light of these considerations, the CSIS-SNL Global Water Futures project offers the following policy recommendations on how to proceed:

- a. The United States is in critical need of a long-range, integrated strategy for international water. In order to develop such a strategy the U.S. government will need to carry out an inventory of existing international water-related policies and projects, identify a lead agency to coordinate the development of an integrated strategy, convene the many departments and agencies in the U.S. Government with established interests and activities relating to water, undertake a global region by region review of resources and needs engaging regional experts, and consult with third-party groups—

i.e., the private sector and the NGO community—to get their feedback and input.

b. As a foundation for the development of an integrated strategy for the United States, we must acknowledge that U.S. international water policy has implications that transcend traditional humanitarian and foreign assistance interests. Water is already a critical element in broader U.S. foreign policy and security interests. It will become all the more significant in the future, especially if the dislocations are allowed to become even more acute.

c. The proposed U.S. international water strategy must be informed by a detailed understanding of the potential impacts of emerging, new technologies and the need for a differentiated approach to the deployment of technology in various regions across the world. This implies the development of partnerships—between government, the private sector, and NGOs—in the development of ideas to “match” technologies with conditions on the ground. This technological plan should be informed by an assessment of optimal use of current technology and by the potential impact of emerging new technology.

d. One key characteristic of the proposed U.S. international water strategy is the identification of realistic goals and metrics to gauge progress and to enable periodic and regular assessments of progress. Such indicators are essential to recalibrating goals and approaches, if necessary. This process should include thorough review and analysis of successes and failures associated with previous water projects.

e. The U.S. international water strategy should include the implementation of pilot projects in different regions and at different scales. These will test the approaches and applications described in this White Paper, promote the continued development of better approaches and applications, and inform the development of larger-scale projects. Regions that should be of highest priority are sub-Saharan Africa, where the flow of funds from international donors has been substantially smaller than the objectively defined needs of water access and water sanitation, and the Middle East, where secure, sustainable water resources are already widely seen as key to political stability.

f. In order to bring such a strategy to fruition, the United States should significantly expand the financial resources it allocates to international water projects. Furthermore, it should redouble its efforts to mobilize public-private partnerships to mobilize resources and deploy technologies. Finally, working with the other G-8 member states and the broader international community,

it should intensify its efforts to catalyze international support to address the challenge of water.

g. The strategy should include a strong awareness and education campaign to elevate water as a foreign policy priority.

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Addressing Our Global Water Future

Center for Strategic and International Studies Sandia National Laboratories

More than 1 billion people on Earth – about one sixth of the global population – currently rely on water sources that are unsafe, unreliable, or difficult to access for their daily washing, drinking, cleaning, and cooking. Nearly one third of the world’s population, or 2.6 billion people, does not have access to basic sanitation (WHO/UNICEF 2004). As a result, millions of people, most of them children, are suffering and dying annually from diseases related to poor water quality (WHO/UNICEF 2000, 2004). Experts believe the scale of this challenge could double in the next two decades (Vörösmarty et al. 2000). Beyond the devastation of lack of access to safe drinking water and improved sanitation, often dubbed the “silent killer” of the developing world (WHO/UNICEF 2004, Reilly and Babbitt 2005), many developed nations must also deal with poor quality drinking water, plummeting water tables, vanishing rivers and wetlands, surface water pollution, and irrigation shortfalls (NIC 2000, Postel 2000, Jackson et al. 2001, Rosegrant et al. 2002).

Global trends in population growth, economic development, industrialization, and urbanization, among others, are pushing all of humanity toward a period marked by unprecedented, sweeping water scarcity, poorer water quality and greater sanitation challenges.¹ By the year 2050, one in four people will live in a country experiencing chronic or recurring shortages of water (Gardner-Outlaw and Engelman 1997). By the year 2025, more people could die of water-related diseases than will perish from the HIV/AIDS pandemic (Gleick 2002a). These trends will have significant consequences for prosperity, stability and security at many scales unless the response to these challenges improves dramatically—starting today.

This new era of water crises presents important risks and opportunities for U.S. international strategic interests. Inaction by the United States and others will lead toward continued economic stagnation in many regions of the globe, may contribute to domestic and international tensions or unrest, and will certainly result in further human suffering and death across the planet. Conversely, proactive, innovative, and coordinated actions by the United States with the international community will advance many major strategic priorities of U.S. foreign policy, including economic development and the building of participatory institutions. Clearly, water can no longer be regarded solely as a tool or byproduct of U.S. development and

¹ See also: United Nations Environment Program, “Vital Water Graphics” Report, 2002; Jean-Francois Rischard, *High Noon: 20 Global Problems, 20 Years to Solve Them*, Basic Books, 2003; UN “Water for Life, 2005-2015” Campaign, <http://www.un.org/waterforlifedecade/reference.html>; Lester R. Brown, *Outgrowing the Earth: The Food Security Challenge in an Age of Falling Water Tables and Rising Temperatures*, Earth Policy Institute, 2004; The World Bank Group, “The World Bank Group’s Program for Water Supply and Sanitation.” 2004.

humanitarian programs. Yet, the most effective means to integrate water projects into the broader international engagement strategy of the United States remain unclear.

This white paper addresses all of the growing global challenges related to increasing water scarcity and declining water quality. The goals of the paper, therefore, are to (1) make the case for elevating the response to global water challenges as a strategic priority for the United States Government; (2) identify the most effective responses to global water challenges; and (3) explore U.S. policy options, current and future.

Many efforts over the past twenty-five years have focused on alleviating water scarcity and providing clean drinking water and sanitation to effected populations across the planet. These efforts provide valuable lessons and successful models for new strategies and actions for new levels of crisis in the future. From these models, it is clear that institutional capacities in governance systems across the world—varied as they are—must all be strengthened to adequately address the magnitude of future challenges involving water. Improving governance will enable and facilitate the development of strategies and responses engaging the full range of available water-related technologies—from high-tech, high expense to low-tech, low expense. Solutions across that range exist today and must be deployed at new and greater scales in order to reduce the impacts on public health, economic development, environmental degradation, and political stability. Continual effort and investment is needed to develop undiscovered technologies, policy approaches and synergies that could jumpstart new solutions in the decades to come. Policy and technology must evolve together to effectively link innovative strategies with innovative technologies. For these reasons, this White Paper emphasizes the development of strategies to address current and future global water challenges with a specific focus on governance and technology and the critical linkages between the two.

This paper is organized into four sections. Section One describes the nature and scope of the global water challenges that face the world. Sections Two and Three explore potential areas for innovation and synergy in policy, governance, capacity building, and the application of technologies. The paper culminates in Section Four with an exploration of how the United States can integrate water into its foreign policy. The text of each section includes and expands upon fourteen “Findings” that emerged from extensive background research and two major workshops sponsored by CSIS and Sandia National Laboratories in early 2005. Together, the elements of this paper link global water challenges to U.S. foreign policy interests, identify the necessary steps for addressing these growing challenges worldwide, and explore strategies for the United States to integrate water into a framework of interrelated foreign policy goals.

Section One: Nature and Scope of Challenge

Why water? Because water is a vital resource for every living organism and ecosystem on Earth. Because problems in governance have created institutions unable to serve the people they represent. Because institutional capacities in many regions have been unable to balance demands across sectors and across boundaries. Because social and spiritual values associated with water have complicated and informed management systems and responses. Because global trends in population, urbanization, economic development, industrialization, migration and other areas have pushed water demand to unsustainable levels.

For all of these complex and dynamic reasons, water related challenges are leading the world into a period in which freshwater will be a severely limiting factor for the economic, social, and political development and stability of countries and populations across the planet. On one hand, global water challenges are the result of too many people demanding too much water. On the other hand, they are a problem of weak institutions and poor governance frameworks unable to manage water supplies to simultaneously meet the needs of people, agriculture, industry, and the environment. This section will outline the growing imbalance between global supply and demand, explore the costs of global water challenges to human health, economies, ecosystems, and geopolitical stability, and identify the institutional barriers to addressing these problems.

Water Supply, Water Demand, Water Quality

In short, steadily increasing global demand for water has already created serious water shortages or will limit the future availability of water to people, agriculture, industry, and/or the environment. Declining water quality further limits this dwindling supply of clean water. Current water usage and management practices are driving increases in demand that are simply unsustainable.

Global Water Supplies Are Unbalanced

The total freshwater resources on Earth available for human consumption on a yearly basis is about 14,000 km³ (Jackson et al. 2001), which equates to only 0.03 percent of all water on the planet. This number translates into 7,000 m³ for every human being on the planet—more than enough water to fulfill each person's

Finding 1: Water scarcity caused by mismanagement and a growing imbalance between supply and demand is driving us toward a tipping point in human history. *Global trends of increasing population, increasing natural resource consumption, and decreasing natural resource availability -- including freshwater-- have pushed many human social, economic and political systems to an important tipping point. Poor management of natural resources exacerbates the problem. We face large-scale future dislocations and crises unless significant action is taken now by leaders in both developed and developing countries.*

daily needs. Unfortunately, most of this 14,000 km³ is located disproportionately to human population settlement and/or is only available for limited times of the year. For example, the Amazon River carries about 15 percent of the Earth's freshwater runoff, but supplies water to less than 1 percent of the world's population (Shiklomanov 1999, Postel 1996). Similarly, well over half of South Asia's water supply falls in the form of precipitation in just three months of the year during the monsoon season.

"We are moving quite rapidly now into what is an unprecedented period of water stress that is not going to ease for some decades, in part because of population growth, in part because of economic growth and the increase in competition for water."

*-Sandra Postel, Global Water Policy Project
CSIS-SNL Global Water Futures Conference 2005*

Box 1: Hydrology 101—hydrologic cycle and sustainable use of freshwater/groundwater.

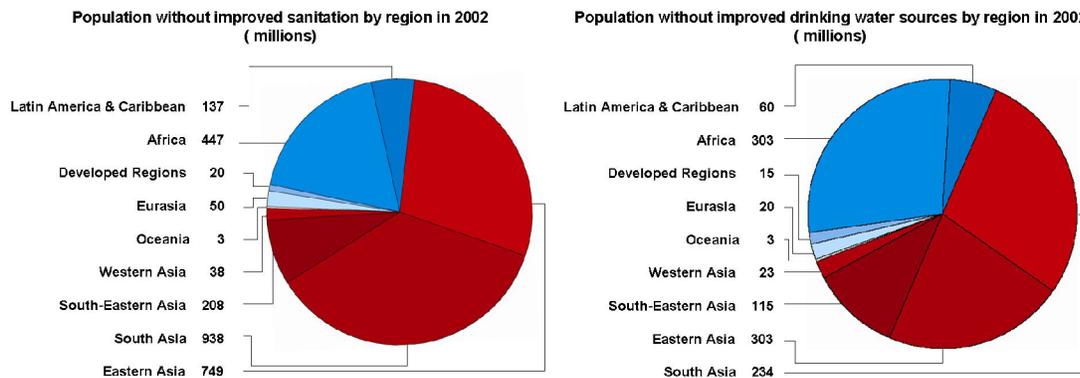
Global freshwater supplies are delivered to terrestrial ecosystems in the form of precipitation derived largely from ocean evaporation. Most of the water delivered as precipitation runs off in rivers and streams back to the ocean. Some of that runoff evaporates and loops back into the hydrologic cycle. Some seeps into underground storage in the pores and crevices of underground geologies, and can be cut out of the hydrologic cycle for days, decades, or millennia. Seepage into these underground reservoirs, or aquifers, can be exceedingly slow, and many aquifers currently being tapped for human uses took thousands of years to fill. In many cases these aquifers are connected to rivers and wetlands on the surface. Because of these linkages, groundwater pumping and the decline of groundwater levels lead to the drying of rivers and wetlands.

In some urban areas around the world groundwater is a major source of water for drinking and other urban uses. Groundwater withdrawal for these uses depletes aquifer levels. Some of the water withdrawn for urban uses is returned to rivers as sewage, and can actually augment surface water flows—though in an undesirable, polluted volume. However, aquifer depletions lead to river depletions. In many cases the transfer of water from ground to river cannot keep pace with the seepage of the river water back into the ground. Integrated freshwater management at any geographic scale must acknowledge these interdependencies.

Human engineering and planning have mitigated the disparities between population and available water supply to a great extent. Dams, reservoirs, storage tanks, pumps, pipes, and other large-scale and small-scale infrastructure capture water runoff from lakes, streams, inland seas, and rivers to deliver for human use. Forty percent of the Earth's total runoff is regulated by 633 large reservoirs with capacities of over 0.5 km³ (UNESCO-WWAP 2003). In addition, groundwater is estimated to provide about 50 percent of the current global potable water supply, 40 percent of the supply for self-supplied industry (meaning industrial production sites that directly pump water from the source), and 20 percent of water use in irrigated agriculture (UNESCO-WWAP 2003). Urban areas are another significant source of groundwater demand, with more than 1.2 billion city dwellers across the world reliant upon well, borehole, and spring sources (UNESCO-WWAP 2003).

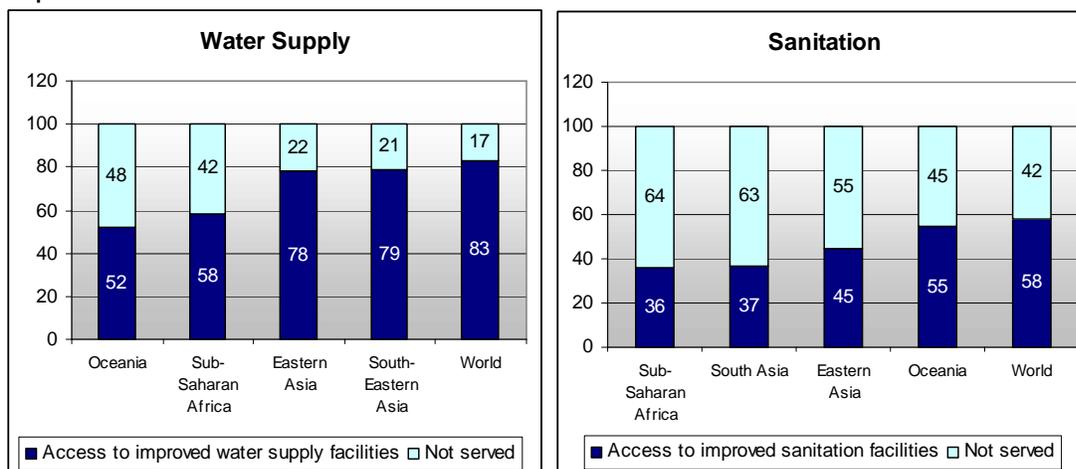
Despite all of the advances in engineering and infrastructure development, the world still has not achieved universal coverage of access to improved sources of drinking water (for definition of an "improved source," see Box 3). Today, 83 percent of the global population drinks water from improved water sources, leaving 1.1 billion people without access to safe drinking water. Of this 1.1 billion without access, two-thirds live in Asia. The situation is perhaps most pronounced in sub-Saharan Africa, however, where over half of the population lacks access to safe drinking water (WHO/UNICEF 2004). In the aggregate, in order to meet the Millennium Development Goals of reducing by one half the number of people without access to safe drinking water, 1.5 billion people will need to be served over the next decade (WHO/UNICEF 2004).

Figure 1: Distribution of unserved populations for water and sanitation



The majority of people lacking access to safe drinking water and sanitation facilities live in Asia (red slices).
 Source: WHO/UNICEF 2004.

Figure 2: Percentage of populations in the most afflicted regions without access to improved water and sanitation facilities



Source: WHO/UNICEF 2004

Declining Water Availability

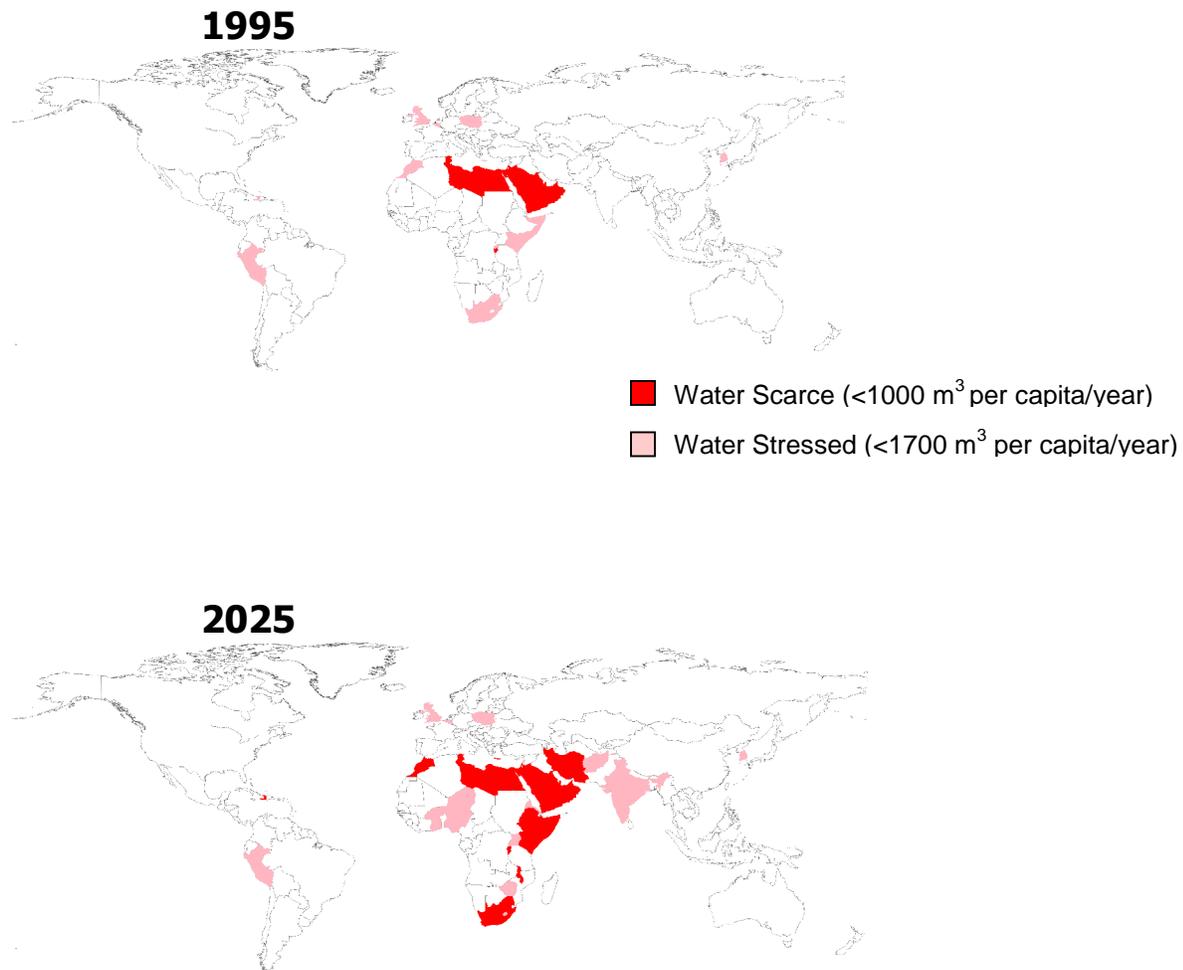
Logically, as the overall world population has increased, per capita water availability has decreased. The imbalance between populations and water supplies in some countries, however, is pushing those countries toward conditions of “water stress” and “water scarcity.” Per capita water availability below 1700 m³/year is considered “water stressed,” meaning water supply problems are common and widespread. One thousand m³/year per capita is considered “water scarce,” the threshold below which serious social, public health, and economic problems arise (Falkenmark and Widstrand 1992). In 1997, by these standards, 270 million people lived in 11 water stressed countries while 166 million people lived in 18 countries experiencing water scarcity. Using United Nations Population Division’s medium projections, by 2025 the number of water stressed countries will rise to 15 and be home to 2.3 billion people. The number of countries experiencing water scarcity will double to reach 39, or 1.7 billion people (Gardner-Outlaw and Engelman 1997).² These numbers do not imply that the billions of people living in these countries will be without water. What they do imply, however, is that these 54 countries, home to almost half of the global population in 2025, will most likely encounter serious constraints in their capacity to meet the demands of individual people and businesses, agriculture, industry, and the environment. Meeting these demands will require extensive planning and careful management of water supplies.

The consequences of declining water availability are evident across the planet. Widespread over-consumption of freshwater resources is causing a collapse in global freshwater ecosystems that will be a primary driver in future water scarcity. Among major rivers that no longer consistently reach the sea are the Colorado River, the Rio Grande, and five of the most important rivers in Asia – the Ganges of India and Bangladesh, the Indus of India and Pakistan, the Syr Darya and Amu Darya in Central Asia, and the Yellow River of China (Postel 2000, Brown 2001, Jackson et al. 2001). Global wetland loss to date is estimated at 26 percent, with losses still occurring around large and small rivers all over the world (Rosegrant et al. 2002).

In many water-scarce regions of the world, the differences between water supply and water demand are made up by engineered water transfers or by pumping groundwater. Declining groundwater levels have occurred in both urban and agricultural regions of the U.S., China, India, Southeast Asia, the Middle East, North

² Differing methodologies account for the variance between the WHO/UNICEF 2004 figures for number of people without access to water and the Gardner-Outlaw and Engelman figures. The former study reached its conclusions by closely defining “improved water source” and distributing questionnaires and household surveys throughout countries covering two-thirds of the world population. The latter study used a previously established methodology for determining a country’s water scarcity by dividing the total water availability for a country by its population. Using this method, people living in countries with significant but concentrated water sources who might in fact lack access to improved water sources, such as in China or India, were not counted. While the WHO/UNICEF study is useful in more accurately quantifying the current state of global water scarcity, future projections are difficult, the aim of the Gardner-Outlaw and Engelman study.

Figure 3: Countries experiencing water stress and water scarcity based on per capita water availability, 1995 & 2025



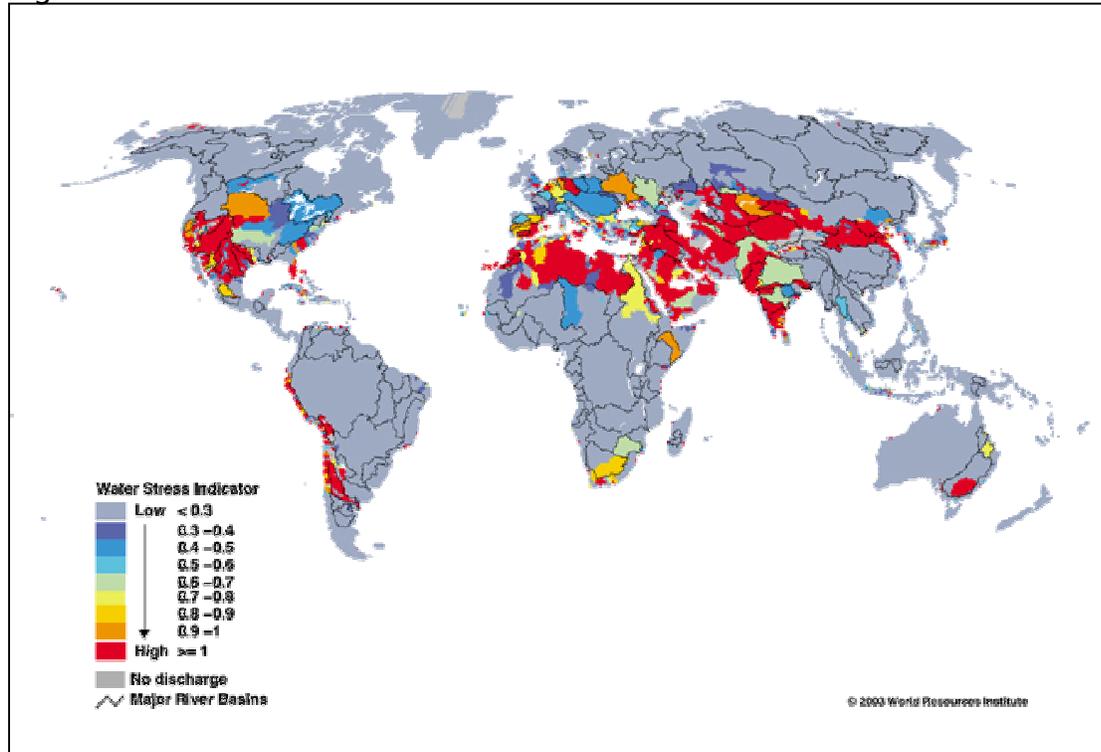
Source: Gardner-Outlaw and Engelman, 1997

Africa, and Mexico (NIC 2000, Postel 2000, Brown 2001, Glennon 2002). For example, since 1965 the shallow water table beneath Beijing, China, has fallen 59 meters; in 1999 alone the water table fell by 1.5 meters (Brown 2001). Beijing's population was 8.5 million in 1975, and is projected to be 11.1 million by 2015 (UNPD 2004a). Such growth will further exacerbate scarcities of water resources for northern China.

In many cases, however, the application of these solutions is unsustainable. The Millennium Ecosystem Assessment (2005) estimates that between 5 and 25 percent of global freshwater use exceeds long-term accessible supplies. In the Middle East and North Africa, up to one third of all water use is unsustainable. Agricultural uses are the biggest concern, with an estimated 15 to 35 percent of irrigation withdrawals in excess of sustainable limits (Millennium Ecosystem Assessment

2005). Libya and Saudi Arabia heavily rely on fossil aquifers—aquifers that are not actively recharged—to supplement water available for irrigation (FAO 2004).

Figure 4: Current water stressed river basins



Source: Smakhtin et al. 2004.

Drivers of Rising Demand

A study conducted at the University of New Hampshire determined that 80 percent of water scarcity in the world could be attributed to rising population and economic development (Vörösmarty et al. 2000). As a result of these forces, water use in the world increased by a factor of six between 1900 and 1995, which is more than double the rate of population growth (WMO 1998). Global freshwater withdrawals in 1990 were about 3500 km³. This level grew to 4,430 km³ by 2000 (Shiklomanov 1999) amounting to between 40 and 50 percent of available runoff (Millennium Ecosystem Assessment 2005). Global withdrawal of water is projected to increase by 10-20 percent every decade reaching approximately 5,240 km³ by 2025 (Shiklomanov 1999).

Projections of future population and consumption trends indicate that demand will be concentrated in specific global regions and urban centers. Efficiency improvements, saturation of per capita demands, and stabilizing populations have led to water withdrawals becoming constant or actually decreasing in many parts of the OECD toward the end of the twentieth century (Millennium Ecosystem Assessment 2005). Outside of the OECD nations, however, global rises in

population, urbanization, industrialization, and economic development and the corresponding rise of energy and food needs are just a few of the trends that are driving rises in demand. These same forces will simultaneously cause shifts in the allocation of water resources between agriculture, industry, and municipal use.

Box 2: Withdrawal vs. Consumption

Humans “use” water by both “withdrawing” and “consuming” it from natural ecosystems. “Withdrawal” refers to all water removed from the ground or diverted from a surface water source, some of which may be returned to the system. “Consumption” refers to water evaporated, transpired, or incorporated into products, plants, or animals and lost from the local system (USGS 2004). The distinction between the two is often drawn when exploring global water challenges and it is important to understand the difference. Consumption is absolute; withdrawal may imply some portion is recycled back into the supply.

By the year 2050, the global human population is expected to rise from the current 6.4 billion to 9.1 billion (UNPD 2004a). In addition, this population will be more urban. Sixty-one percent of the world population will live in cities by the year 2030—particularly in the less developed world where urban populations are expected to double (UNPD 2004b). The development of mega-cities—urban centers with populations over 10 million—throughout the world creates a whole set of resource supply and demand issues that current and future societies must face, including the provision of safe, clean drinking water. Cities in this category now include Mumbai, Kolkata, Jakarta, Manila, Seoul, Beijing, Shanghai, Tianjin, Lagos, Mexico City (topping the population list at 21 million), Sao Paolo, Rio de Janeiro and Buenos Aires (Harleman and Murcott 1999.)

Regionally, those areas of the world with some of the greatest quality and supply issues will be growing the fastest over the next two decades. Asia, Africa, and South America will increase withdrawals by 46, 54, and 56 percent, respectively, with increases in consumption in those three regions ranging from 34 to 38 percent (Shiklomanov 1999). While global water demand will increase overall, certain sectors will increase faster than others through the year 2025. Although we can expect a decline in industrial water withdrawals in developed countries, this decrease is more than offset by a projected increase in developing countries with growing industrial demand. In this instance, measures of industrial withdrawal include water used for the generation of electricity, which helps to explain the significant upward drive for demand. Municipal use in the developing world will also increase sharply, but in absolute terms agriculture will still withdraw over five times as much water as municipal uses and three times as much as industry (Cosgrove and Rijsberman 2000).

Meeting Rising Food Demand

Agricultural withdrawals dominate current global water usages, constituting 66 percent of all global water withdrawals and 85 percent of total water consumption. In fact in Asia, sub-Saharan Africa, and MENA, agriculture accounts for 85-90

percent of total water usage (Shiklomanov and Rodda 2003). Increasing global populations are certain to increase demand for food and the water needed to produce it. In the past, rising food demand has been met through an expansion of arable land (largely through irrigation), increased crop intensities (i.e., the ability to plant more crops more often on one field), and a growth in crop yield (i.e., gaining more food products from a single plant). Expanding irrigation will play a significant role in increasing the productivity of current and future arable land and meeting rising food demand. However, several constraints exist for such an expansion in the future.

The area of irrigated land will need to expand by 20-30 percent to meet growing food demand, if current production and irrigation methods remain constant (Cosgrove and Rijsberman 2000). Water scarcity, soil losses, lack of financial resources, slowdown in dam construction and other infrastructure improvements, or competition for space with urban areas will limit the extent to which expanding irrigated land is feasible (Cosgrove and Rijsberman 2000). Furthermore, in order to meet growing food needs, the FAO (2003) estimates water withdrawals by 2030 for irrigation must increase by 14 percent in developing countries, many of which are already experiencing water shortages or wreaking havoc on the natural environment. Without an increase in productivity through improved cropping intensities and crop yield, constraints on available water and land could lead to devastating food shortages (Cosgrove and Rijsberman 2000).

These risks could be mitigated through improved irrigation efficiencies. In addition to being the largest water user, agriculture is also the most inefficient. Only 40 percent of the water withdrawn actually reaches crops (UNESCO-WWAP 2003). The other 60 percent is lost along the way to evaporation, transpiration by non-crop species, or seepage into the ground.³ A critical challenge in the coming decades will be to increase and maximize food production through sustainable water use.

Water Demand for Industrial and Energy Production

As the second largest water user worldwide and the largest water user in the developed world, industry (including power generation⁴) will also play a significant

³ In some cases, the non-crop evapotranspiration supports local vegetation that has value to local residents for creating shade, supporting biodiversity, and enhancing landscape aesthetics. In some cases, too, agricultural seepage returns to nearby rivers, or recharges shallow and deep aquifers, and so does not represent a complete loss.

⁴ Characterizing global industrial water use is difficult for several reasons. Definitions of “industrial use” vary between countries, sometimes combining and sometimes not combining manufacturing and power production. Figures given in this section for global “industrial” withdrawal refer to both manufacturing and power production. Furthermore, water consumption varies greatly between different manufacturing processes, and between manufacturing and power production. Many manufacturing and power plants withdraw a great deal of water, but also return most of it to the natural system or pass it along for other human uses – although the water being returned may be impaired in various ways. Finally, many manufacturing and power plants withdraw their water supply directly from the natural system rather than from a municipal supply. Many countries do not

role in future water management. At issue with industrial facilities are the quantities of water withdrawn and the quality of water returned to the natural water system. Industrial withdrawals of water are expected to rise by 55 percent from 752 km³ per year in 1995 to 1170 km³ per year in 2025 (Shiklomanov 1999). The bulk of this increase will come from the developing world as countries continue to industrialize. In high-income countries, water withdrawals for industry account for 59 percent of total water use (Clarke and King 2004). This level has remained stable since the 1980's in large part due to gains in water efficiency resulting from more stringent regulations, reformed water pricing, and improved technologies. A portion of these improvements, however, also stems from moving water-intensive manufacturing processes to developing countries (Cosgrove and Rijsberman 2000, OECD 1998). The biggest water-consuming industries—chemical, oil and petroleum, wood products (including pulp and paper), food processing, steel, iron and metallurgy, and textiles—will become increasingly common in the developing world, where water-saving techniques and technologies are not as widespread or available. Currently, water use per unit of output in transition economies is two to three times higher than in OECD countries (Cosgrove and Rijsberman 2000). Such inefficient use will undoubtedly cut into the amount of water available for municipal and agricultural use.

A recent study conducted by Exxon-Mobil projects that between the years 2001 and 2030, global electricity production will more than double, from approximately 12,000 to 27,000 terawatt-hours annually (ExxonMobil 2004). Linkages between electricity generation and water usage will be key drivers regarding how and where this growth will actually take place. On a large scale, water and electricity are linked in two ways: (1) the direct use of water to produce electricity through hydropower facilities; and (2) the use of water as a coolant in thermo-electric power generation using fossil fuels, and in nuclear generation facilities.

Hydroelectric power provides 19 percent of the total electricity production worldwide (UNESCO-WWAP 2003). Overall, about one-third of the economically viable large hydropower sites in the world have already been developed, with Asia, Latin America, and, to a lesser extent, Africa offering the greatest potential for growth in the near term. Hydropower systems vary from small run-of-the-river systems in the kilowatt range, to large turbines involving dams and reservoirs in the hundreds of megawatts. The smaller systems are generally employed in rural areas, have little (or manageable) environmental impact, consume no water, and provide power on a local basis. Many questions remain, however, on the environmental and social costs associated with hydroelectric power projects. The global debate over the efficacy and value of large dams has led to an overall decrease in the expansion of such projects.

measure water that is provided to industrial facilities from municipal sources, meaning industrial use is often underestimated (OECD 1998).

More than 40 percent of growth in electrical production out to the year 2030 will take place in Asia, and will be based principally on coal and natural-gas-fueled plants (ExxonMobil 2004). Overall, about 80 percent of the world's electricity production comes from nuclear and fossil fuel plants, where large amounts of water are used to remove waste heat from the processes. Several closely linked factors determine the potential impacts on associated water demand. First, once-through cooling systems use more water and can be more environmentally disruptive than recirculating cooling systems. In the former, the amount of water withdrawn from a source is much higher than the amount actually consumed through evaporation. Second, once-through systems, being less costly, are generally employed where there is an abundant supply of surface water, while recirculating systems are used when an aquifer is the main source. Finally, higher efficiency electric plants produce less waste heat per kilowatt-hour, requiring less cooling water. Thus, natural gas-fired combined cycle plants, which run at over 50 percent efficiency, require far less water than coal-fired steam plants or nuclear plants (with efficiencies between 30 percent and 40 percent).

Water Pollution

Declining water quality across the world is constraining global freshwater supplies. By the year 2050, untreated wastewater could reduce the world's freshwater resources by as much as 18,000 km³ annually (UNESCO-WWAP 2003). That is the equivalent of over a third of the global annual renewable supply of about 49,000 km³ (Gleick 1998) or almost four times the annual flow of the Amazon River. The overall negative impacts of this contamination on human health, the environment, and industrial and agricultural productivity will be felt throughout the world. The range of water contaminants and sources differ across socioeconomic strata and geographic boundaries, but the effects will be most severe in developing countries lacking the resources or capacities to expand water treatment regulations and infrastructure.

The pollutants and pollution problems for specific countries or regions can vary widely due to economic status, types of industry and agriculture, geography, climate, geology and more. However, water quality improvements around the world are hampered by weak regulatory frameworks, weak institutional capacities to enforce existing regulations, and inadequate financial resources and/or political will to invest in pollution-preventing technologies. Developing nations suffer largely from water quality problems related to untreated human and industrial waste. In developing countries, 90-95 percent of all sewage and 70 percent of industrial waste is released untreated into surface water (Millennium Ecosystem Assessment 2005). Developed countries have largely addressed the challenge of treating human waste and some industrial effluent, but now face what are as-yet largely unquantified problems associated with solvents, metals, pharmaceuticals, endocrine disruptors, fuel additives, and petrochemicals that find their way into ground and surface waters.

Increasing industrialization in the developing world brings with it concerns over growing pollution levels. Industry typically consumes just over 10 percent of the water it withdraws, releasing the rest as wastewater of varying quality. Between 300 million and 500 million tons of heavy metals, solvents, toxic sludge and other wastes accumulate in water sources each year as a result of industrial processes (UNESCO-WWAP 2003). Of gravest concern are organic pollutants, such as PCBs and DDT, which remain in the ecosystem for long periods, travel throughout the food chain, travel long distances, and carry serious health consequences for humans. In China, where the problem is most severe, 7 million kg of organic water pollutants are discharged each day accounting for 36 percent of global organic water pollutant emissions (World Bank 2005).

All nations engaged in modern agriculture have varying levels of water quality problems associated with fertilizers, herbicides and pesticides. Addition of nutrients to fresh and coastal water sources from human sewage and from fertilizers that run off agricultural fields is one of the leading water quality problems around the world with well-known, far-reaching implications, and it has been shown to increase with rising population (Caraco and Cole 1999). Nitrogen inputs can devastate natural ecosystems and commercially important fish populations by promoting the growth of algae and weeds. Decomposition of those algae and weeds by bacteria lead to oxygen depletion that kills or drives away aquatic animals. Nitrogen inputs have approximately doubled since pre-industrial times (Vitousek et al. 1997) and the Millennium Ecosystem Assessment (2005) estimates that nitrogen levels will increase by 10 to 20 percent in developing nations.

Beyond these well-documented and understood classes of pollutants, tens of thousands of synthetic chemicals are released into the environment without any kind of monitoring or regulation (USEPA 2002). Many of these chemicals can be extremely persistent in the biosphere and little is known about their short- or long-term ecological and public health impacts, or their synergistic effects in combination with other chemicals. Data on the discharge of chemicals like these for other countries in the world is sparse. Discharges will likely increase as countries industrialize.

Two additional sources of groundwater pollution—increased soil salinity and naturally occurring trace elements—stem from naturally occurring elements in the environment, but become harmful through human intervention or inaction. First, overdraft of groundwater sources can lead to saltwater intrusion along coastal areas, contaminating freshwater aquifers with salt water. Surface water salinities can increase dramatically in semi-arid and arid agricultural river systems as river water is diverted for irrigation, returned to rivers with higher concentrations of dissolved solids picked up from soils, then used for irrigation again and again farther downstream (UNESCO-WWAP 2003). Soils irrigated with highly saline water become

salinated themselves. According to Shiklomanov, 30 percent of the world's irrigated area suffers from salinity problems (forthcoming, quoted in UNESCO-WWAP 2003).

Naturally occurring fluoride and arsenic present an added health risk for populations in many developing countries. In China, over one million people currently suffer from skeletal fluorosis, a painful condition caused by excessive amounts of fluoride in the drinking water that changes bone structure and calcifies the ligaments (WHO 2004). The costs are prohibitive for many of the preventative measures to remove excess fluoride from the drinking water supply. Naturally occurring arsenic also threatens human health and well being in Argentina, Bangladesh, Chile, China, India, Mexico, Thailand and the United States. The situation in Bangladesh is, perhaps, most tragic. During the 1970s, millions of boreholes and wells were drilled in Bangladesh to provide a source of drinking water safer than the shallow wells and the flooding Ganges. Unfortunately, in 1993 the deeper well water was found to be contaminated with arsenic stemming from the geological strata beneath Bangladesh. Today, 90 percent of Bangladeshis rely on arsenic-contaminated well water for their source of drinking water, resulting in over 100,000 cases of skin lesions (WHO 2001). In the next few decades, skin and internal cancers are expected to begin afflicting larger segments of the population. Between 35 million and 77 million of the country's 130 million inhabitants will be affected, according to some estimates (UNESCO-WWAP 2003).

The Costs of Global Water Challenges

Water is essential to every aspect of human life and can play both a beneficial and immensely disruptive role to human health and activities. Too much water in the form of floods leads to widespread destruction and devastation, followed by disease and dislocation; too little water, in the form of drought or insufficient infrastructure for meeting needs, causes famine, stunts economic development, and disproportionately affects women, children, and the poor. When water supplies are well managed and predictably provide adequate amounts of water, they serve as the building blocks of a productive and stable society. The presence or absence of a well-managed, predictable, and safe water supply significantly impacts human health, economic development, and geopolitical stability.

Finding 2: Water is a foundation for human prosperity. *Adequate, high-quality water supplies provide a basis for the growth and development of human social, economic, cultural and political systems. Conversely, economic stagnation and political instability will persist or worsen in those regions where the quality and reliability of water supplies remain uncertain.*

Inadequate Water Supply and Sanitation

Humans need very little water just to survive from day to day, but they need much more water to prosper. To live and live well, people need both a clean, reliable, and accessible source of water and adequate, improved sanitation. Treatment of human sewage plays an important role in issues related to water and human health and well being for two reasons: (1) water is an integral part of most modern sanitation treatment processes; and (2) human (and livestock) waste are a leading source of water pollution. Two million tons of human waste is released into streams and rivers around the world every day (UNESCO-WWAP 2003), and that number is much higher if livestock wastes are included. Today, over 1.1 billion people lack access to safe water and 2.6 billion people lack access to improved sanitation (WHO/UNICEF 2004).⁵ The causes of these statistics are extremely complex, but their effects can be measured in terms of human health and well-being, as well as in economic costs.

"Water is a critical unit for sustainable development in every society and economy."

-Robert Ayers, ITT Industries
CSIS-SNL Global Water Futures
Conference 2005

"We need to go beyond looking at water as a utility. We need to look at it in its regional and macro-economic development and nation-building efforts."

-Jerome Delli Priscoli, US Army Corp
of Engineers
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Problems of water access and sanitation vary greatly between urban and rural settings in both scope and source of problems. Eighty percent of people without access to sanitation live in rural areas, totaling 1.3 billion people in rural India and China alone (UNESCO-WWAP 2003). Roughly one third of all people living in rural areas lacks access to improved drinking water sources (CSD 2004a). Collecting water in these areas, most often the job of women and girls, can take up to five hours a day and typically involves a journey of 10 miles with heavy loads (WaterAid, World Bank 2003). With rising urbanization across the world, however, water scarcity will become an increasingly urban issue. In order to meet the Millennium Development Goals of halving the proportion of people without access to basic sanitation, 1 billion people in urban areas and 900 million people in rural areas will need to be served (WHO/UNICEF 2004).

Of particular concern are the impoverished slums and informal settlements growing in and around urban centers across the world. In these areas, adequate drinking water supplies are scarce and inadequate sanitation and sewage treatment services are leading to widespread water and environmental contamination from human waste (CSD 2004b). Currently, 928 million people are living in slums around the world (UN HABITAT 2003). As Anna Tibaijuka, director of UN Habitat, warns, "The battle for water and sanitation will have to be fought... in the slums and shanties of

⁵ Previous estimates counted 2.4 billion in the world people lacked access to improved sanitation. The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) revised the number upward to 2.6 billion (2004)

the growing urban areas of developing countries (UNESCO-WWAP 2003).” The distance to a water supply in urban areas may be closer than in rural ones, but high population densities cause long lines at the pump and a shortage of sanitation facilities. In addition, these impoverished populations are often situated in close proximity to poorly regulated industrial zones that release untreated waste into the water supply. All these factors can conspire to make urban water supplies and sanitation facilities no more accessible or safe to the poor than rural water (UNESCO-WWAP 2003).

BOX 3: WHO/UNICEF Definitions of Water Supply and Sanitation Technologies Considered to be “Improved” and “Not Improved”

Improved drinking water source:

Household connection
Public standpipe
Borehole
Protected dug well
Protected spring
Rainwater collection

Improved sanitation facility:

Connection to a public sewer
Connection to a septic system
Pour-flush latrine
Simple pit latrine*
Ventilated improved pit latrine

Unimproved drinking water source:

Unprotected well
Unprotected spring
Rivers or ponds
Vendor-provided water
Bottled water**
Tanker truck water

Unimproved sanitation facility:

Public or shared latrine
Open pit latrine
Bucket latrine

*Only a portion of poorly defined latrines are included in sanitation coverage estimates.

**Bottled water is not considered improved due to limitations in the potential quantity, not quality, of the water.

(Source: WHO/UNICEF 2004)

Consequences for Individuals

The consequences of inadequate water supply and sanitation are most severe for individuals. To begin with, the human health costs are dramatic. Five million people die every year as a result of waterborne diseases or water-related illnesses. Intestinal parasites infect about 10 percent of people in developing nations; 6 million people are blind from trachoma; 200 million are infected with schistosomiasis and 20 million suffer severe consequences from the disease. All these problems and many more are related to poor water quality and lack of sanitation (WHO and UNICEF 2000). Gleick (2004a) estimates that current trends will result in the deaths of between 30 and 50 million people from water-related diseases by the year 2020.

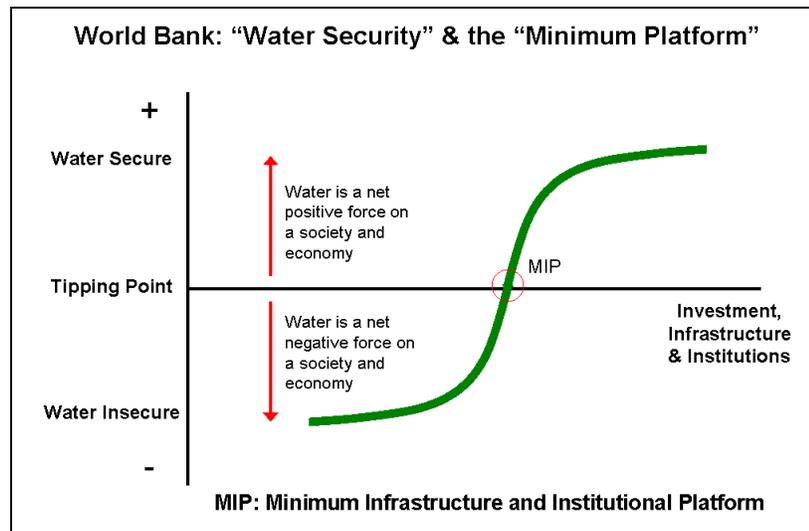
Individual productivity is severely limited by sickness and deaths related to poor water quality. As the Commission on Sustainable Development (CSD) (2004a) states, "The rural poor generally do not pay for water with cash but with time and energy spent fetching water..." In Africa, 40 billion working hours are lost each year to carrying water (Cosgrove and Rijsberman 1998). In India, waterborne diseases cost 73 million lost working days and \$600 million in medical treatment and lost production (Lenton and Wright 2004). Inadequate sanitation services at schools and the responsibility of gathering water keeps young girls out of school. One school sanitation program begun in 1990 has increased total enrollment of girls by 11 percent annually (WaterAid 2003). Finally, urban populations in developing countries not connected to a tap often pay ten to twenty times more for water delivered by a truck than water that is delivered to other city residents through a pipe (Cosgrove and Rijsberman 2000). Without access to adequate water supply and sanitation, the world's poor are limited, either by disease or the need to gather water, from economically productive activities that could lift them out of poverty. They also suffer a greater financial burden in accessing water.

Consequences for Nations

On a larger scale, the ability to manage water supplies, ensure water quality, and mitigate seasonal variability in precipitation and river flows heavily influences a country's economic development through agricultural and industrial output, transportation, energy production, and minimizing property damages from floods. Countries with adequate infrastructure and institutions to balance low flows and high flows across geographic and temporal barriers are able to protect water quality and capitalize on the productive benefits of water while minimizing the risks. For these countries, water represents a net positive force for the economy. In contrast, for countries susceptible to variations in water flow or unable to ensure its quality, water represents a significant barrier to economic growth.

The World Bank, at the most recent CSD meeting in April 2005, presented a paper to a panel of finance ministers that introduced a "Water and Growth S-Curve" (Grey and Sadoff 2005) (see Figure 5). The paper first defined water security as "the reliable availability of an acceptable quantity and quality of water for production, livelihoods and health, coupled with an acceptable level of risk of high social and economic impacts of unpredictable water events." Water security essentially sets the "tipping point" at which water has either a net positive or net negative effect on an economy. The S-curve illustrates that as countries invest more in infrastructure and institutions, water security increases. In order for water to be a net positive force on a society and economy, a country must develop a "minimum infrastructure and institutional platform (Grey and Sadoff 2005)."

Figure 5: World Bank 'Water and Growth S-Curve'



Source: Derived from World Bank, Water Resources, Growth and Development, 2005

Box 4: Reading the Water Security S-Curve

The water security S-curve relates the level of investment in infrastructure and institutions with the level of water security. Investments in infrastructure can range from simple hand-pumps to large-scale dams, water treatment, and water delivery systems. "Institutions" refers to the regulatory frameworks, management bodies, and enforcement capacities related to employing the infrastructure to withdraw and deliver water for human personal and economic consumption or to mitigate water-related risks such as drought and flood. Water security simply means the extent to which both infrastructure and institutions are providing sufficient quantities and qualities of water for human personal and economic consumption, as well as mitigating potential damage from and protecting against droughts and floods.

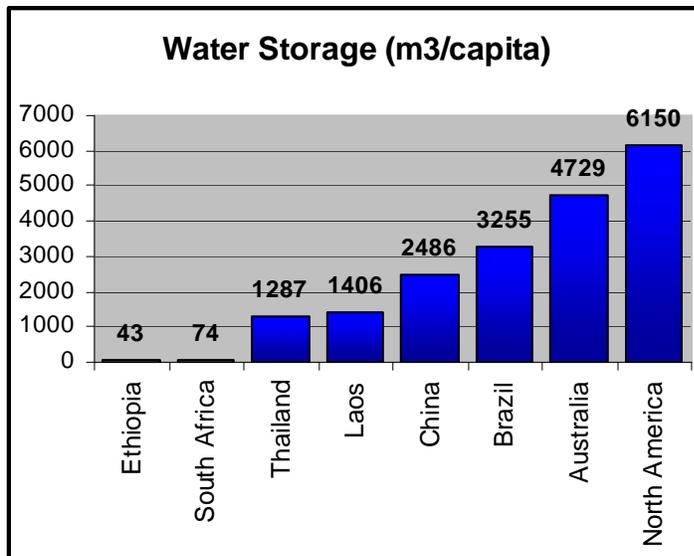
In Figure 5, the red S-curve represents the water security of a hypothetical Country A. As Country A adds hand pumps, wells, rainwater catchments, and small-scale water treatment, the S-curve rises slowly. These smaller scale technologies will help local populations gain access to water or help them store water safely over time. However, these smaller scale technologies may not be widely available throughout the country, or they may be over-taxed, with too many people relying on single pumps and wells. Whatever the case, the infrastructure is insufficient and water remains a net drain on the economy and human development. In other words, the infrastructure does not provide sufficient levels of water access. Poor water quality causes disease and death, and/or water-related natural disasters remain a significant risk.

As Country A adds more advanced types of infrastructure, such as dams, large-scale water treatment facilities, advanced irrigation networks, etc., and develops the complementary institutions to construct and manage that infrastructure, the S-curve rises more rapidly. The curve continues to rise rapidly until it crosses the "tipping point" or "minimum infrastructure and investment platform" (MIP). Above this point, water-related infrastructure and the relevant institutions provide sufficient quantities and qualities of water for human and economic prosperity. Stable and advanced irrigation practices would improve the productivity of agriculture. Water-related diseases would no longer hinder human productivity. No longer having to collect and carry water long distances, women would be able to devote more attention to other economic activities and children would be able to attend schools. The private sector is willing to invest in capital expenditures because the threat of disruptions caused by flood or drought has subsided. In other words, water becomes a net benefit to the economy and society.

Source: Grey and Sadoff 2005.

Infrastructure is the most important factor in determining a country's place on the S-Curve and, consequently, its level of economic development. The ability to store water is one measure of infrastructure. Figure 6 shows per capita water storage capabilities for a range of countries. Infrastructure mitigates water variability and ensures quality to support agricultural and industrial output, maintain transportation networks, and minimize property damages from flooding. Three case studies illustrate the relationship between water infrastructure and economic development. In the Tamil Nadu region of India, irrigated districts averaged only 25 percent poverty rates compared to 70 percent in un-irrigated districts. In Kenya, the El Niño flood and subsequent La Niña drought caused estimated damages equivalent to 11 percent and 16 percent of GDP in 1998-99 and 1999-2000 financial years (Grey and Sadoff 2005). Over 90 percent of the calculated flood losses were related to transportation and water supply and sanitation damage, while the majority of the losses caused by the droughts were associated with foregone hydropower (26%) and industrial production (58%) (Grey and Sadoff 2005).

Figure 6: Water storage per capita

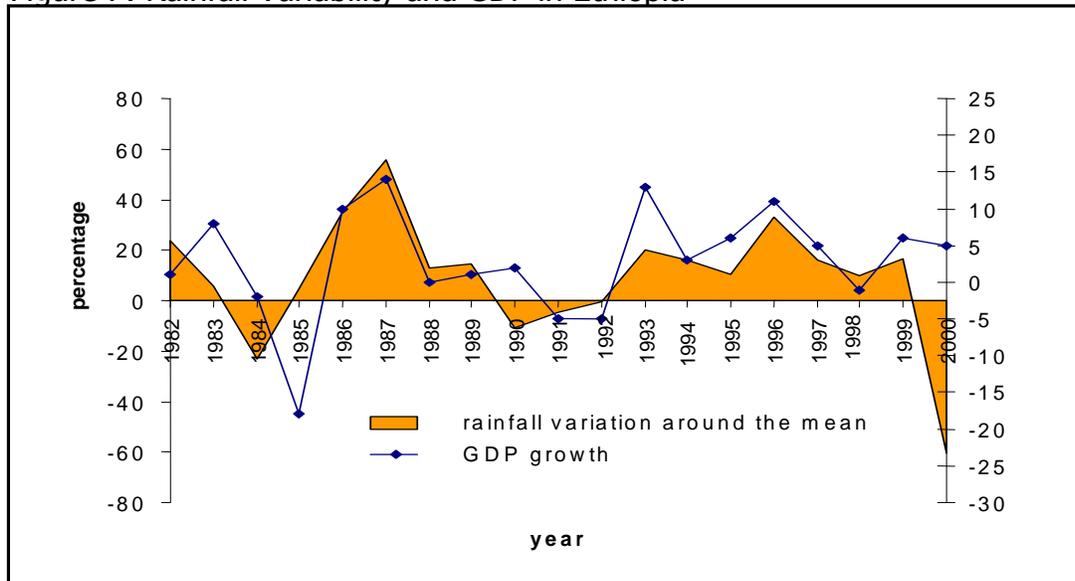


Source: World Bank 2005

Finally, in Ethiopia, where only 43 m³ of water storage capacity per capita have been developed compared to 6,150 m³ per capita in North America, variability in rainfall and the rise and fall of national GDP are closely linked (see Figure 7). In addition, the road network and food aid dependence are tied to hydrology. Ethiopia's highly rugged terrain coupled with the torrential tropical rains drive up the cost and engineering difficulties in building roads. As a result, 90 percent of Ethiopia's roads are dry weather roads. When the rains come and farmers are able to grow crops, the roads to the markets are impassable; when it does not rain, the crops fail but the food aid trucks are able to travel throughout the country (Grey and Sadoff

2005). For countries like Ethiopia and Kenya, lack of infrastructure and water insecurity not only directly hurt their economies, but indirectly ward off potential investors, both foreign and domestic. As the World Bank report notes, "In the poorest countries, where survival is a real concern for large parts of the population and there are few functional social safety nets, economic actors tend to be extremely risk averse, investing only after there is significant demonstration of returns (Grey and Sadoff 2005)."

Figure 7: Rainfall Variability and GDP in Ethiopia



Source: Grey and Sadoff 2005

Environmental Consequences for Economic Growth

Ecosystem degradation caused by water withdrawals, loss of wetlands, and water pollution will also hinder economic development by affecting ecosystem services. Ecosystem services are the conditions and processes through which natural ecosystems, and the species that comprise them, sustain and fulfill human life. These services include purification and delivery of fresh water, decomposition of wastes, generation of soils, pollination of crops, production of wood and fiber, and many more (Daily 1997). The ecosystem services provided to humans by freshwater systems, including aquifers, wetlands, lakes, streams, and rivers, fall generally into three categories: a) the supply of water for drinking, irrigation and industry; b) the supply of other valuable and diverse goods, such as fish, waterfowl, grazing mammals and other animals that live near freshwater sources; and c) and non-extractive, or "in stream", benefits including transportation, flood control, waste disposal, property values near scenic lakes or rivers, urban parks, and recreation (Postel and Carpenter 1997).

Ecosystem services have very large impacts on human economic systems. A pioneering study found that global freshwater resources provided ecosystem

services to humans at a 1994 value of at least \$6.6 trillion. The study found that the entire value of global ecosystem services for that year was \$33 trillion. At that time the global gross national product was about \$18 trillion—meaning that ecosystems services in general, and those associated with water in particular, heavily subsidized the human economy (Costanza et al. 1997).

A water project in New York offers a specific case in point, and may be instructive for water managers in other parts of the world. By 1996 New York City's drinking water supply was becoming increasingly polluted with sewage, fertilizers and pesticides. A filtration plant would have cost the city \$8 billion, and another \$300 million annually for operation and maintenance. Instead, the city spent more than \$1 billion to purchase land and restore watersheds in the Catskill Mountains, where New York City's drinking water supply originates. Restoring the ecosystem services provided by well-functioning watersheds saved New York City over \$6 billion, excluding annual costs, and was equally effective relative to the much more costly alternative of a filtration plant (Jackson et al. 2001).

One more benefit of functioning ecosystems is biodiversity, or the abundance and variety of species at all scales. Biodiversity, in turn, is considered to be important for maintaining the function and stability of ecosystems, and the delivery of ecosystem services (Tilman 1997). The World Wildlife Fund's Freshwater Species Population Index (FSPI), which measures the average change over time in the populations of 194 species of freshwater birds, mammals, reptiles, amphibians and fish, fell by over 50 percent from 1970 to 1999. Globally, 20 percent of freshwater fish species are already threatened or extinct, and freshwater species make up 47 percent of all animals federally endangered in the United States (Jackson et al. 2001).

Water and Geopolitical Stability

Taken together, all of these factors—from the rising imbalance of supply and demand to the devastating effects of water on human prosperity—point toward a world in which growing water challenges could ignite the underlying economic forces that may lead to conflict and war in the future. Such warnings have been voiced by leaders and scholars across the planet—from U.N. Secretary Generals Kofi Annan and Boutros Boutros Ghali to the U.S. National Intelligence Council. These warnings should certainly be weighed heavily, but the inevitability of conflict solely over water resources remains uncertain. Historical data on international interactions regarding water show many more cooperative arrangements than conflicts. In fact, the last

Finding 3: Water problems are geopolitically destabilizing.

Water scarcity and poor water quality have the potential to destabilize isolated regions within countries, whole countries, or entire regions sharing limited sources of water. There is an increasing likelihood of social strife and even armed conflict resulting from the pressures of water scarcity and mismanagement.

incident of full-out war over water occurred 4,500 years ago between two Mesopotamian city-states (Postel and Wolf 2001). On the other hand, from 2000-2003, 15 violent conflicts across the world involved water either directly or indirectly. Twelve of these were related to disputes over the development of shared water resources (Gleick 2004a). While history gives cause for comfort, increasing water scarcity and declining water quality across the world certainly present the threat of increased instability and conflict in the future. Defining the exact nature of that threat is the first step to avoiding unrest or dangerous disputes.

"[E]ver-increasing global demand for the scarce water resources that we have will almost certainly lead to future geopolitical conflicts. And we need to find ways to head that off."

-Sen. Jeff Bingaman

CSIS-SNL Global Water Futures Conference 2005

"Tension over water issues is driving today conflict in a wide variety of local, national and transnational settings."

-Amb. C. Paul Robinson, fmr. Sandia National Laboratories

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In the future, instability or conflict related to water supplies will likely take two forms: (1) domestic unrest caused by the inability of governments to meet the food, industrial, and municipal needs of its citizens, and (2) hostility between two or more countries—or regions within a country—possibly leading to greater insecurity or conflict, caused by one party disrupting the water supply of another.

Domestic Unrest

Numerous instances of domestic unrest have erupted recently related to governments' management of water resources. In April 2005, thousands of peasant farmers in China's Zhejiang province violently protested government concessions to a local factory that had been polluting the land and water causing wide spread sickness and poor crop yields. The farmers' pleas to Beijing and provincial authorities had largely gone unanswered (Cody 2005). In India, riots raged through September and October 2002 over the allocation of the Cauvery River between Karnataka and Tamil Nadu. On the other side of the planet, in Cochabamba, Bolivia, 30,000 protestors managed to reverse the government's decision to privatize the municipal water utility after several days of violent protest, which left one person dead and more than a hundred injured (Gleick 2004a).

In each of these instances, civil unrest was directed toward governments, but private corporations can also fall victim to public discontent. Protests have also been taking place in the state of Kerala over the alleged over-withdrawal of groundwater and pollution by Coca-Cola. The public outcry is partially organized and supported by a one-man nongovernmental organization watchdog in California, demonstrating how increased flows of knowledge and information enable any sized group to exert significant pressure on any issue across long distances. As resource scarcities increase and water quality is threatened throughout the world, many similar types of watchdog organizations could mobilize public discontent or insecurity

to act against governments or individual corporations (Stecklow 2005, Basu and Leith 2005).

These case studies are just a sampling of the many water-related incidents of unrest arising across the world. They represent the consequences of rising imbalances in water availability and the failures of governments to effectively and transparently mediate the concerns and demands of various users. These dislocations illustrate the direct correlation between governance and disorder—greater stability stems from greater capacities of government institutions to reconcile the demands of urban and rural populations as well as the agriculture, industry, commercial, and domestic sectors; more instances of unrest follow lower levels of government transparency and responsiveness. Unfortunately, government transparency and responsiveness are not widespread in many regions experiencing rising pollution and increasing water scarcity. As a result, problems in governance can be expected to further escalate. These shortcomings may cause domestic disputes and unrest linked to poor water quality and water scarcity.

Food Security

Irrigation and food production will significantly impact geopolitical stability and international relations in the coming decades. As populations grow and become increasingly urbanized, global food production will need to increase to meet demand. Today, 40 percent of food produced in the developing world relies on irrigated agriculture. This level will need to be expanded by 14 percent in order to meet demand. Such an increase becomes less viable with dropping groundwater and surface water levels. According to Sandra Postel and Aaron Wolf (2001), "China, India, Iran, and Pakistan are among the countries where a significant share of the irrigated land is now jeopardized by groundwater depletion, scarce river water, a fertility-sapping buildup of salts in the soil, or some combination of these factors." The potential for arousing tensions and instigating conflict both within their borders and with their neighbors increases as these countries look for additional sources of water or seek to improve their infrastructures to meet demand.

Some countries will have to decide to what degree they should maintain an agricultural sector at all. It takes about 900 liters of water to produce one kilogram of wheat, 1900 liters to produce one kilogram of rice, and 15,000 liters to produce one kilogram of beef (Clarke and King 2004). Increasing water scarcities raise questions of which crops are necessary and at what level of production to ensure food security. Studies show that when water availability drops below 1500 cubic meters per capita per year, countries begin to import food, and particularly water intense crops (Yang et al. 2003). Twenty-one countries fell below this threshold in 2000 and another 14 will join them by the year 2030 (Yang et al. 2003). Furthermore, when 40 percent of renewable water resources are devoted to irrigation, countries are often forced to decide between allocating water to the agricultural sector or to the urban municipal and industrial sector. By 2030, South

Asia will reach that 40 percent level and the Middle East and North Africa region will have hit 58 percent (UNESCO-WWAP 2003). In short, the number of food importers across the world is likely to increase, along with the possibility of domestic unrest related to irrigation shortages. Geopolitical balances will be affected by the alliances between food-importing countries and those countries supplying the food.

Cross-border, International Conflicts

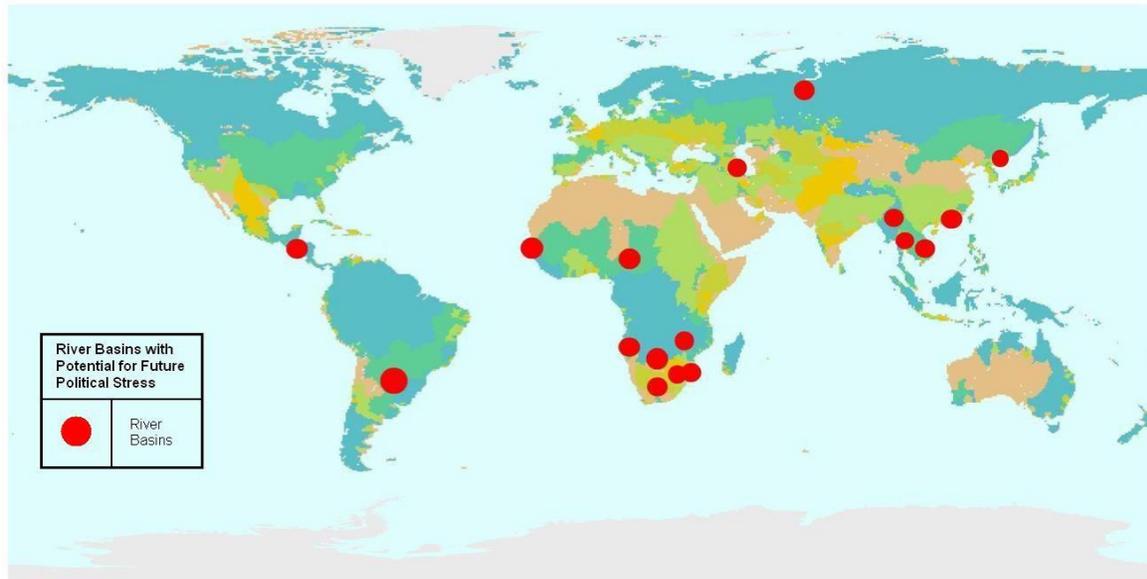
Mediating concerns over water uses among the agricultural, industrial, and domestic sectors, the environment, local interests, national interests, economic development, and the reduction of poverty is sufficiently demanding. However, the challenge is further complicated when geopolitical international pressures are added to the equation. Forty percent of the world's population lives in more than 260 international river basins of major social and economic importance, 13 of which are shared by five or more countries. Disputes and conflicts have already erupted and could easily erupt again as increasing water scarcity raises the stakes.

As Wolf et al. (2003) illustrate, the likelihood of a cross-border conflict increases when either the physical or institutional aspect of river basin management is altered and the institutional capacities to cope with these changes are overstretched. Examples of such disruptions include the initiation of a large-scale engineering project, such as a large dam, river diversion, or irrigation scheme, without the consultation of other riparian or downstream users, or the break up of a single nation into several newly independent states. Without a treaty or other binding agreement to spell out each country's rights or responsibilities, the situation quickly deteriorates into a "protracted period of regional insecurity and hostility, typically followed by a long and arduous process of dispute resolution (Postel and Wolf 2001)." Using these criteria – rapid change occurring in a hostile and/or institution-less basin – Wolf et al. (2003) identified seventeen river basins at risk of water conflict over the next five to ten years. These basins include the Ganges-Brahmaputra, Han, Incomati, Kunene, Kura-Araks, Lake Chad, La Plata, Lempa, Limpopo, Mekong, Ob (Ertis), Okavango, Orange, Salween, Senegal, Tumen and Zambezi.

Strong, well-conceived and innovative international agreements over water sharing are a logical step toward avoiding future conflicts that may occur. Most water agreements currently govern navigation or ensure a downstream nation's rights to water, and most are established bi-laterally. Implicit or explicit in these agreements is an obligation to give prior notice to riparian nations about new constructions or alterations to the flow of a shared waterway (Cosgrove 2003). However, no universal international law addressing these issues exists, nor does any international governing body that could moderate a dispute over these issues between two countries. In 1997, the UN Convention on the Non-Navigational Use of International Watercourses did set out a framework that was approved by 103 countries in the UN General Assembly, but as of 2005 only 14 states had ratified it.

Figure 8: Conflict is likely to arise in river basins lacking an institutional framework to mediate water-sharing agreements.

River Basins with Greatest Potential for Future Political Stress



Source: CIESIN et al., 2000; Fekete et al., 1999.

Projection: Geographic

Map produced by the World Resources Institute, 2000.

Source: Wolf et al. 2003

Poor Governance, Poor Countries

Traditionally, water supplies have been viewed as a public good and governments have largely been charged with distribution and management of this strategic resource. Although the role of the private sector in water distribution and management is rising, water responsibilities in most parts of the world still remain in the domain of governments. These responsibilities include increasing supply, mitigating demand, developing infrastructure for economic development, and mediating cross border management. In practice, government institutions must secure enough political will and financial resources to initiate any sort of response. There is a general deficit in all of these requisites—good governance and strong

Finding 4: Poor governance and poor economies contribute to and exacerbate water scarcity problems. *Poor governance and poor economies in regions around the world where water challenges are most severe impair the effective application of either innovative technology or innovative policy. Furthermore, poor governance creates a disincentive to the mobilization of international and domestic financial resources. Solutions to water problems must therefore be linked to improvements in governance.*

institutions, adequate financial investment, and political will—that is as much a cause of global water challenges as rising population, migration, urbanization, and economic development.

Many governments today are unable to fulfill their mandate to provide safe, adequate supplies of water for their population. These governments also fail to provide adequate water for economic activities and for the needs of the environment. Moreover, many water authorities are disproportionately providing water access to the richer segments of society, while ignoring the needs of the poorest. Regulatory frameworks and pricing structures do not provide adequate incentives for efficiency or water quality. Legal institutions are not sufficiently robust to enforce frameworks that are in place. Individual capacities of water suppliers and water users are not developed to facilitate an open and responsive exchange. Subsidies often encourage over-use by certain sectors, especially agriculture and industry. The incentives for water providers to expand, maintain, and improve infrastructure are insufficient. These examples provide a sampling of the issues associated with water governance.

“And that is the issue – not so much of the resource not existing, but the resource being inaccessible, being economically inaccessible.”

-*Claudia Sadoff, World Bank
CSIS-SNL Global Water Futures
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“So while we talk about [water] as a global problem, the reality is that it really is a shared national problem, and I would submit that the key obstacle – the most important obstacle to really making progress on this issue, is the lack of political will.”

-*Bruce Scherr, Natural Resource
Defense Council
CSIS-SNL Global Water Futures
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Overall, the fundamental problems of water management and governance are twofold: an absence of appropriate institutions and chronic dysfunction of institutions at all levels. Specific water governance concerns differ across all nations but can be grouped into three broad categories: institutional and regulatory environments, the tensions between central and periphery management, and governance capacity.

Improving Governance

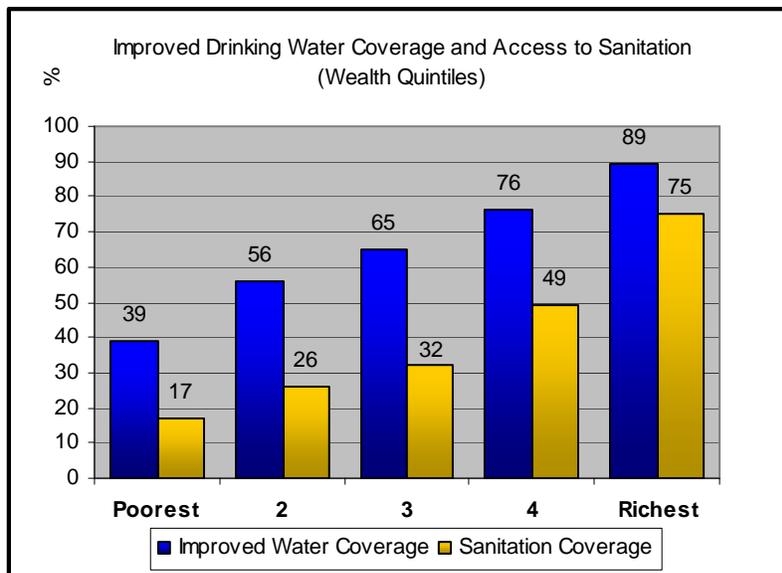
In theory, water management institutions regulate who gets what, when they will get it and how much of it they will get to ensure that the demands of all water users are satisfied. However, as delivery networks have expanded, the role, burden, and institutional authority of each stakeholder on both sides of the supply-demand equation have become blurred. This confusion over responsibilities and expectations has often lead to poorly funded and managed institutions unable to provide adequate quantities and quality of water to all users.

In practice, the breakdown of water management institutions can be traced to a general lack of incentives for providing water access to the poor. For example, governments perceive that other development projects, such as roads or energy

infrastructure, would have higher returns, private utilities believe the poor are unable to pay. Either a government-funded or private-sector expansion of infrastructure into informal urban settlements may be delayed because the legal disposition of the communities is uncertain (Lenton et al. 2005). Figure 9 illustrates the disparities in coverage between the richest and poorest segments of society. As the United Nations Millennium Project (Lenton et al. 2005) has noted, "So long as water supply and sanitation service providers are reliant upon the state for budgetary transfers, and so long as agency staff are vulnerable to interference by officials in decisions relat[ing to] their careers, priority setting, pricing, and investment will continue to favor those with political connections—which almost never include the poor."

A firm regulatory system can provide certain incentives to bridge the gap in providing water services to the poor by ensuring both quality and economic standards are being met. Quality regulation monitors both the quality of the water provided as well as the service providing it. Economic regulation, i.e., tariff setting, ensures the interests of both operators and users are protected (Lenton et al. 2005). Within a well-enforced regulatory system, the rights of water users to adequate quantities and quality water are protected as are the rights of producers to collect compensation for the services they provide. Thus, users are given an incentive to pay and providers are given an incentive to offer better, expanded service.

Fig. 9: The poorest are the least served.



Source: WHO/UNICEF 2004.

The mere existence of regulatory rules and policies, however, means little if these frameworks are undermined by power politics, entrenched interests, a lack of funding, or the absence of local communities from the decision making process (UNESCO-WWAP 2003). In countries where water management is largely

centralized, many local water issues are trumped by the larger national interest. As a result, the voices of many vital local stakeholders (indigenous people, the poor, women, etc.) are stifled. In other countries where power has devolved from the center, the responsibility for water management has been transferred to the local level but the actual power to make decisions, particularly on financial matters, has proven much harder to separate from the central government—a contradiction that leads to poor governance (GWP 2004). To avoid these pitfalls, many experts currently argue that water should be managed at the lowest appropriate level of governance, to ensure greater accountability and provide solutions specific to the needs of the community or region (UNESCO-WWAP 2003, Lenton et al. 2005, Ribot 2002, GWP 2004).

In theory, such a “decentralization” of water management would allow water users—from individuals lacking access to safe drinking water or sanitation to farmers and manufacturers—to become more directly involved in the process of water management. Greater engagement of local interests would lead to longer-lasting, more sustainable solutions by incorporating local knowledge, better addressing local needs, and creating community buy-in. The actual process of decentralization could take several forms. Power could be transferred to an organization, such as an irrigation association, representative of and “downwardly accountable” to local populations or water users. Alternatively, the central government could grant greater autonomy to local branches of government (Ribot 2002).

In practice, the process of formal decentralization has proven difficult. The Egyptian government has initiated several pilot programs to transfer more responsibilities for operation and maintenance (O&M) of irrigation and drainage systems to local farmers. Historically, the central government has been responsible for O&M of irrigation ditches down to the level of branch canal, a heavy financial and managerial burden for the state. By increasing farmers’ participation in irrigation improvements, the government hopes to motivate farmers to invest more in maintaining irrigation systems, as well as making irrigation systems and irrigated agriculture more sustainable. However, a survey of the four main pilot projects shows that there is widespread resistance to the idea of farmers assuming O&M responsibilities beyond the farm level. Poor education levels, political disorganization as a result of heterogeneous socioeconomic makeup, and poor communication with the government were identified as the main barriers to successful adoption (Moustafa 2004). Participants in a workshop organized by the Asian Development Bank also identified low levels of education, sharp societal divides, bureaucratic impediments, and possible corruption as obstacles for civil society to take on the roles that would make decentralization more effective (Pigram 2001). Another downside of a decentralized approach is the possibility of local efforts undermining other water users’ interests within a river basin or across water sheds.

Clearly, if greater local participation in management of water resources is to be successful, capacities will need to be improved in all levels of government and among local community organizations. At the highest level, development of institutions and individuals alike are essential for the successful introduction of new regulatory systems (GWP 2004). Shoring up technical, financial, managerial, and social intermediation capacities at every managerial level is necessary. Greater technical knowledge leads to more innovative and appropriate solutions at the local level. Understanding of financial mechanisms and accounting practices attract more investment and bring greater accountability. As central or provincial government agencies take on greater oversight, the managerial and conflict resolution skills of their officials will need to be honed. Finally, social intermediation professionals who can collaborate with the poor and understand the needs of men, women, and children will be essential (Lenton et al. 2005).

Familiarizing all stakeholders with the various options for managing water is a complementary step in this process (GWP 2004). At the local level, some degree of capacity building and information sharing is necessary to ensure community members and households understand their rights and options for gaining access to water. Without these capacities, vital stakeholders risk losing the abilities to defend any new informal and formal rights from competing interests (UNESCO-WWAP 2003).

Increasing Financial Resources

Taken together, improving institutional and regulatory environments, building governance capacity, and encouraging appropriate local participation will go a long way toward improving governance. Improved governance, in turn, will push governments to expand water access and improve water quality across the world.

Yet, governance alone will not sufficiently address the massive challenges ahead. Recent cost estimates for meeting the Millennium Development Goals of reducing by one half the number of people without access to water and sanitation range from \$57-\$63 billion for clean water and \$29-42 billion⁶ for sanitation (Lenton et al. 2005) for a total of \$86-105 billion or \$5 billion each year over the next ten years. However, this estimate is only for meeting direct human consumption demand and does not include the rising demand for agriculture and industry. The World Water Vision, conducted by the Global Water Partnership, has estimated total investment needs at \$180 billion each year from 2000 – 2025 for new infrastructure alone for a

⁶ Assumptions used in arriving at these estimates include the following: (1) estimates are for a “minimum package,” meaning low service levels for rural populations and intermediate service levels for urban populations; (2) costs for specific technologies were averaged; (3) estimates include only direct construction costs and not other program delivery costs; (4) population growth was accounted for but unit costs were constant; (5) sanitation costs are given on a per facility basis and water costs are given on a per capita basis; and (6) the 200 million slum dwellers targeted in the Millennium Development Goals are assumed to be distributed over the regions in relation to the proportion of urban population unserved in the entire region in 2000 (Lenton et al. 2005).

total of \$4.5 trillion (Cosgrove and Rijsberman 2000). This estimate does not include repairing damages from age and neglect of existing systems. Even if these estimates are wildly off the mark, two conclusions remain self evident: (1) significant levels of capital must be raised to address the world's growing water problems; and (2) government-raised funds are not going to be enough to cover the capital expense—especially when taking into consideration the fact that much of this cost is rooted in revenue-poor developing world countries.

Figure 10: Estimates for meeting the Millennium Development Goals for Water and Sanitation range from \$99 billion to \$139 billion.

Cost estimates for reaching the Millennium Development targets for water and sanitation, 2005-2015 (Billions of US Dollars)			
Source of estimate	Water target	Sanitation target	Total
Vision 21	57	42	99
Joint Monitoring Program	63	29	92
Nigam and Ghosh (1995)	51	24	75
Briscoe and Garn (1994)	102	37	139

Source: Lenton et al. 2005.

Figure 11: World Water Vision Estimates a total of \$4.5 trillion will need to be spent on improving water infrastructure over the next two decades.

Annual Investment Requirements for Water Resources (Billion of US Dollars)		
Use	1995	2025
Agriculture	30-35	30
Environment and industry	10-15	75
Water supply and sanitation	30	75
Total:	70-80	180

Source: Cosgrove and Rijsberman 2000

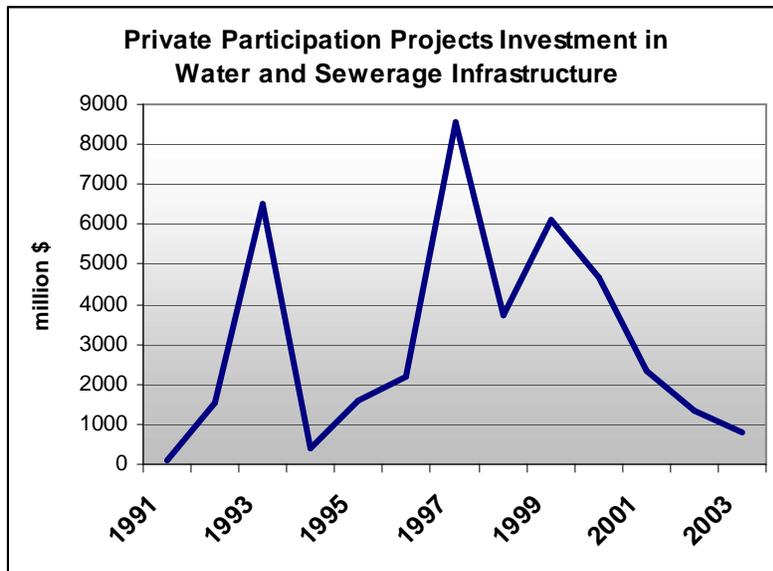
Today, an estimated \$75 billion a year is spent on water services – including drinking water, sanitation and hygiene, municipal wastewater treatment, industrial effluent, agriculture, and environmental protection (Camdessus 2003). Of that amount, about 65 percent comes from government, 20 percent from the private sector ranging from small water vendors to private municipal and metropolitan utilities, 10 percent from international donors, and the remainder from the international private sector (Cosgrove and Rijsberman 2000). Current annual official development assistance (ODA) combined with the contribution of international financial institutions (IFIs) averaged \$3.1 billion from 1999-2001 (OECD 2003). Added to the \$4.5 billion contributed by the private sector, it becomes clear that

governments will have to look within their own borders for the bulk of the required capital (Hecht 2004).

This fact will continue to hold true in the future as both private investment and official development assistance are declining and are not reaching the regions with the greatest needs. Private sector investment in all types of infrastructure in developing and industrialized countries declined from an all time high of over \$120 billion in 1997 to under \$50 billion in 2002 (Lenton et al. 2005). Official development assistance for water also declined slightly during this time frame, dropping from an average of \$3.5 billion between 1996 and 1998 to \$3.1 billion between 1999 and 2001. Compared to overall ODA, water ranks as a low priority, accounting for 6 percent of bilateral aid and some 4-5 percent of multilateral aid in the 1990s (Benn 2003).

Both private investment and official development assistance have also avoided the regions of greatest need. Between 1990 and 1997, less than 0.2 percent of private sector investment in water and sanitation went to sub-Saharan Africa and from 2001-2002 less than 16 percent of total foreign aid to the water sector went to countries where less than 60 percent of the population had access to an improved water source, including most of the least-developed countries (Lenton et al. 2005).

Figure 12: Declining Private Investment in Water and Sewerage Projects



Source: World Bank 2004

These decreases and the unbalanced concentration of investment by the private sector, foreign donors, and international financial institutions are a direct result of the lack of confidence these institutions hold for the governance capacities of the countries with the greatest need. A large portion of the projects funded by official

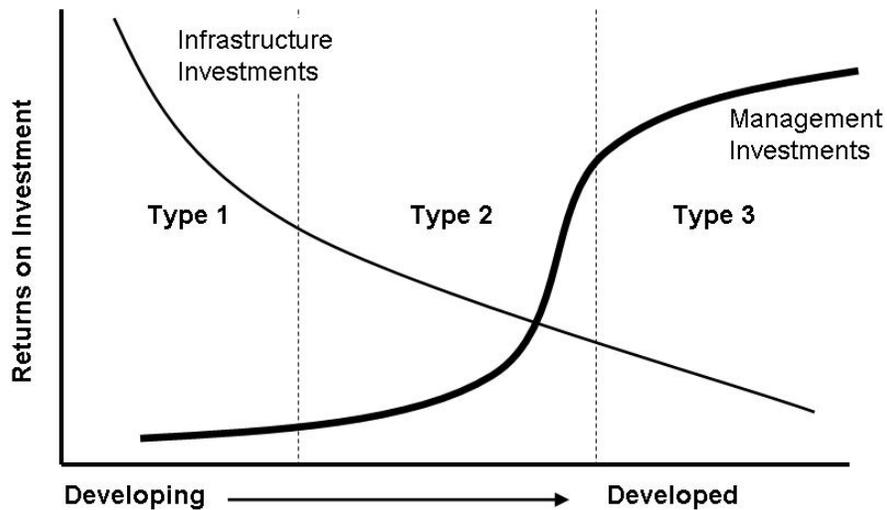
development assistance are devoted to “large systems” for urban areas, while only 10 percent of aid in the water sector is directed to water resource policy, planning and programs (Benn 2003). This disparity demonstrates that investment is attracted to countries with stronger governance structures—i.e. those countries with the institutions to develop integrated and participatory water development projects, with the capacity to manage a project after its completion, and the regulatory framework and legal institutions to protect private investments. Yet, it could also be said to demonstrate that this capital is rarely committed to building such institutions. To some extent, this disparity reflects the reluctance with which funding agencies undertake the very difficult task of effecting changes in governance.

Returning to the World Bank’s Water Security S-Curve (Fig. 13), investment in both institutions and infrastructure are needed along the entire curve, but the sequencing and “proportionality” given to each is dependant on a country’s place on the curve. When infrastructure is low, emphasis is placed on expanding water infrastructure stocks. As these stocks develop, however, a need for expanded institutional capacities arises (Grey and Sadoff 2005). Many of the countries currently struggling with water and sanitation coverage face a combination of factors—greater hydrologic variability, more international river basins, higher flood risks—that require greater investment to reach the tipping point of water security. Many of these same countries also face governance barriers—corruption, weak institutions, poor regulatory frameworks—that repel the international sources of investment that could move them closer to water security.

Lackluster political will for actions toward addressing global water challenges is a problem both within the countries with the greatest needs and among international donor countries. As the UN Millennium Project (Lenton et al. 2005) notes, “The kinds of changes needed to prioritize improved water supply and sanitation services to poor households often threaten status quo arrangements that confer substantial benefits on politically influential groups.” Furthermore, developing countries often face a host of problems and political leaders are not well attuned to the social and economic benefits of improving water supply and sanitation infrastructure. Overcrowding of issues and a lack of awareness is a similar concern in the international arena. Many international initiatives have tried to bring global water challenges to the forefront. The United Nations has declared 2005-2015 the “International Decade of Action – Water for Life” following the 2003 Year of Freshwater, the commitments made by G-8 leaders in 2002 at the Evian Summit, and the declarations heard at the World Summit for Sustainable Development at Johannesburg in 2002. Still, many international efforts remain uncoordinated and miss those areas with the greatest needs. Political will to work together, coordinate actions, and get aid to those countries that most need it will be necessary to address the grave water challenges we face in the future.

Figure 13: Investment Priorities in Water Infrastructure and Management Through Progressive Stages of Development

Balancing & sequencing investments in water infrastructure & management



Type One Countries	Type Two Countries	Type Three Countries
Infrastructure stocks are so low that investments in management do not have very high returns; emphasis should be placed on developing minimum infrastructure platform.	Absence of large-scale, sophisticated infrastructure does not provide incentives to adopt sophisticated management practices; countries should concurrently develop pragmatic infrastructure needs and management systems.	Significant infrastructure investments have been made; focus should be on improving integrated management practices.
Low-income countries: Ethiopia, Kenya, Mozambique	Middle-income countries: India, South Africa	Developed countries: The Netherlands, United States, Japan

Source: Grey and Sadoff 2005.

Section Two: Building Capacities and Building Solutions

The challenges laid out in Section One are formidable, but the options available for addressing these challenges are more numerous and better understood than ever before. Over the past two decades, several international forums have focused on global freshwater issues, countless local and international nongovernmental organizations have mobilized to improve access to water and sanitation, and even private corporations have engaged on issues of freshwater sustainability. The solutions and conclusions offered in this section are the direct result these international actors' decades of experience, without which the innovative ideas for future solutions presented here would not be possible. It is important to recognize that in mobilizing the entire constellation of solutions to global water challenges, innovative approaches that change the current rate of progress will be necessary. Success will not be brought about by simply more of the same. Instead, it will be realized by leveraging all of the institutional knowledge and technological knowledge available to create reinforcing successes.

In shifting focus from the problems to the solutions, this section begins with a look at the meaning of "sustainable" or "self-perpetuating" solutions and then explores the institutional foundations for achieving sustainability of solutions. Section Three follows with an exploration of the possible combinations of technology and policy. Institutions—whether they are national governments, water management bodies, regional cooperative frameworks, public-private partnerships, etc.—are ultimately responsible for assessing the problem and implementing the solutions. For this reason, Section Two examines the ideal characteristics and benefits of strong, participatory institutions and ways to shore up their ability to react to water-related challenges through multi-sectoral partnerships and through new economic models. Together, participatory institutions, multi-sectoral partnerships, and new economic models will form the bedrock of sustainable solutions.

"Sustainable" Solutions

Before delving into the institutional, policy, or technology oriented solutions, it is important to understand why sustainable solutions are essential and what makes a solution sustainable. In short, many past strategies to challenges of water supply and quality have been narrowly focused or one-dimensional engineered approaches. Failure to address the root causes led to improvements in water availability or water quality for those that were afflicted at the time, but these improvements were either short-lived or did not prevent the problem's expansion

Finding 5: Solutions must be innovative, revolutionary, and self-sustaining. *Current trajectories for improvement in freshwater availability and quality are inadequate to meet global needs in a timely way. Innovative solutions must be found and employed that replace steady, incremental rates of progress with dramatic, revolutionary changes. These solutions must be designed to be self-sustaining over the long-term.*

as populations grew or migrated. Looking forward, “sustainable solutions” will be innovative, will be conducted in a strategic framework, and will lead toward long-term successes.

Approaches for international development adopted during the Cold War—mostly including one-time, one-dimensional projects—were effective over the short term, but have not stood the test of time. For example, over one billion people were connected to safe water supplies during the first International Decade for Clean Drinking Water, from 1981-1990. Unfortunately, many of the wells that were dug during that decade have been contaminated, water levels are dropping, populations are growing, and today 1.1 billion people still lack access to safe drinking water. Sub-Saharan Africa is not on track for meeting the Millennium Development Goals and the countries of East Asia and the Pacific are making marginal progress (See Figure 14). In response, the United Nations has declared a second international decade for safe drinking water, the “International Decade for Action: Water for Life” from 2005-2015.⁷

“I’ve seen a lot of iterations of this but as a global community in 2000 we set a goal of having, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation, and I would submit that unless there’s some sort of fundamental change in the way we think about these problems and approach these problems, we’re not really going to make a dent in solving this problem and meeting this target.”

*Jacob Scherr, Natural Resource Defense Council
CSIS-SNL Global Water Futures Conference 2005*

“With a little restructuring here and there, I believe this decade can be the start of a whole new program and a whole new process. So that is a world vision. It’s a global vision. It demands partners and partnerships to make it actually work.”

*Amb. John McDonald, Institute for Multi-Track Diplomacy
CSIS-SNL Global Water Futures Conference 2005*

In order for the efforts of this new decade to be successful, and to avoid the need for a third international decade for action, solutions enacted today must be different from solutions enacted in the past. Population growth, funding limitations, inadequate operation and maintenance, inadequate cost recovery, insufficient trained personnel, and continuation of a “business as usual” approach employing traditional policies, resources, and technologies have all been cited as reasons for the first decade falling short of universal access to safe drinking water and sanitation (Mintz et. al 2001). Accordingly, solutions enacted in the future should move beyond providing “more of the same” by changing the trajectory of current progress. In order to meet global requirements, they must yield exponential progress – or “step changes” – rather than linear progress. In other words, they must follow the same trajectories as the forces that are causing global water challenges—population growth, economic development, industrialization, etc. All of the solutions outlined in this report are measured against this standard of success.

⁷ For more information on the International Decade for Action, visit <http://www.un.org/waterforlifedecade/index.html>

Sustainable solutions generally exhibit three characteristics. First, they are strategic. Water is a strategic resource, meaning it is vitally important to human prosperity, economic development, environmental health, and political and geopolitical stability. The most effective solutions will recognize this importance and leverage the different roles water plays in each of these areas. Second, sustainable solutions are innovative. Innovation can stem from not only entirely new solutions, but also new applications and new mixes of past solutions. Finally, sustainable solutions are effective over the long-term. Long-term solutions not only extend the lifespan of solutions implemented today, but also leverage the next generations of innovations and successes in an ever-rising upward spiral. Strategic, innovative, long-term approaches will be necessary in solving the global water challenges of both today and tomorrow.

Figure 14: Progress on Attaining Millennium Development Goal 7
(Target: Halve the proportion of people without access to improved water sources)□

	Achieved	On Track	Lagging	Far Behind	Slipping Back	No Data
Sub-Saharan Africa	1	9	4	9	0	21
East Asia and the Pacific	0	6	1	4	0	8
South Asia	3	4	0	0	0	1
Arab States	0	8	0	3	0	6
Latin America and the Caribbean	1	21	1	2	0	8
Central and East Europe and the CIS	0	8	0	0	0	17

Source: UNESCO-WWAP 2003

Participatory Management and Governance

The foundation for any sustainable solution will be the institutional framework in which it is created and implemented. As Ölcay Ünver, former president of the Greater Anatolia Project (GAP) in Turkey, has noted, “Sustainability...implies that institutions, not just individuals, are key actors and hopefully active in their roles (Ünver 2001). The overwhelming consensus among international organizations, governments, aid agencies, the private sector, nongovernmental organizations, and others directly involved in addressing the world’s water issues is that an institutionalized integrated approach to water management and

Finding 6: Participatory principles strengthen sustainable solutions. *Effective water planning and management at local and regional levels requires a broad and integrated collaboration, including farmers, urban developers, environmentalists, industrialists, policy makers, citizens, and others, all within an open and participatory framework. Water improvement and management projects conducted at local and regional levels that promote the principles of multi-stakeholder processes and open communication can play a dual role as democracy-building projects.*

development initiatives must be pursued. This approach must strike a balance between economic, social and environmental interests. The concept of “integrated water resource management” (IWRM) is heralded as a means to overcome the traditional sectoral treatment of water and give consideration to the multiple uses of the resource. Furthermore, it provides a framework in which to develop partnerships and reconcile the numerous interests associated with water resources. The following paragraphs will outline the concept of integrated water resource management, explore the many benefits of an IWRM framework, and identify strategies for effective implementation.

The Concept of Integrated Water Resource Management

IWRM, as defined by the Global Water Partnership, entails “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (Global Water Partnership, 2004). The strength of IWRM in the development of sustainable strategies is drawn from its integration across multiple dimensions. Effective water management must consider both the physical dimension of the water resource, which is related to its location, type, quantity, and quality, and the nonphysical dimension (Jønch-Clausen and Fugl 2001). The nonphysical dimension embodies the interests, habits, education levels, cultural predilections, preferences and objectives of the broad array of water users, as well as broader ecological, political and economic goals imposed by society. Integration must occur both within and across all these dimensions, taking into account variability in both time and space (Jønch-Clausen and Fugl, 2001). It is achieved in part through collaboration in which diverse and often competing stakeholders work with technical experts and with decision-makers to frame an issue and develop possible solutions (Jønch-Clausen 2004, Spash 2001, Connick and Innes 2003).

A framework to move towards effective IWRM must ensure the concurrent development and strengthening of three elements: (1) an enabling political and regulatory environment comprised of clear policies and regulations enforced by strong institutions; (2) appropriate institutional roles for all stakeholders; and (3) practical management tools and approaches drawn from policy, technology and

“Local politicians, city planners, farmers, agri-businesses, manufacturers, and citizens must be equally involved in water planning and decision making.”

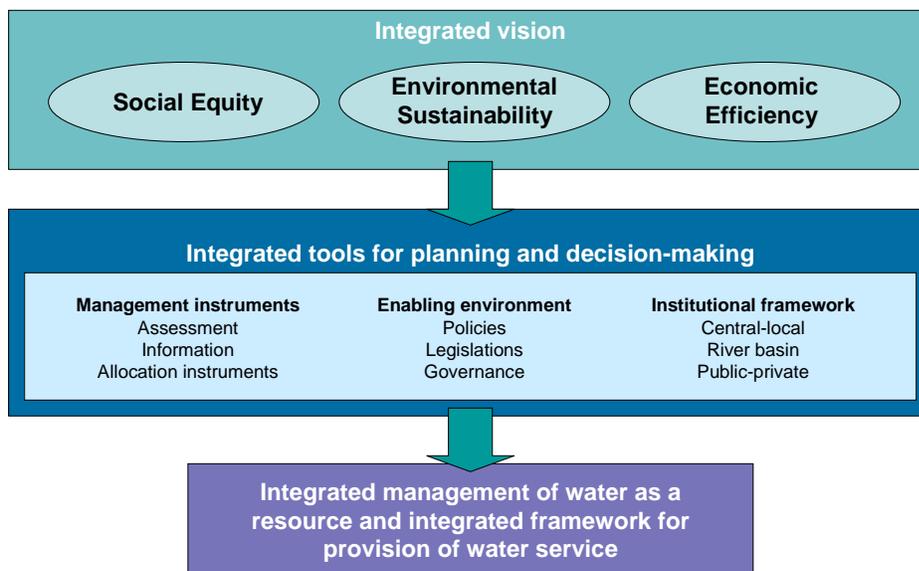
*-Steven R. Loranger, ITT Industries
CSIS-SNL Global Water Futures
Conference 2005*

“We found that you can get people from – in urban poor areas from different ethnic groups to work together if everybody understands that they have equal participation. We found that you can get communities and their local government officials to negotiate and talk together about how to do work together to address their water and sanitation issues, especially around extending water lines and making sure that the water is available at a fair price.”

*-Steven Werner, Water For People
CSIS-SNL Global Water Futures
Conference 2005*

economics that help water managers select, adjust, and apply the right mix of tools and approaches for a given situation (Global Water Partnership, 2004). The enabling environment comprises policies and legislation at all levels and fosters inter-sectoral cooperation (Jønch-Clausen and Fugl, 2001). The development of a water-sensitive political economy requires coordinated policy making at all levels from national ministries to local government or community-based institutions. Additionally, the existence of clear policies and a legal-regulatory framework grants institutions the authority to enforce the rules. Institutional development is critical to the formulation and implementation of IWRM policies. The associated institutional framework communicates the roles of respective stakeholders who make use of the management instruments. The collaborative, multi-stakeholder approach has been applied in numerous regions around North America (Baker et al. 2004; Tidwell et al. 2004; van den Belt 2004), Central Asia (Barber et al. 2005), and in other regions (see WSSCC 2003).

Figure 15. Building a Framework for Integrated Water Resource Management (IWRM)



Source: UNESCO/WWAP, 2003

BOX 5: New Levels of Integrated Water Resource Management

There are numerous cases around the United States and the world in which water from one watershed is piped or pumped into another watershed, sometimes on a very large scale. “The watershed” has become widely acknowledged as the preferred unit of water management, but in these cases “progressive water management” would consider the two connected watersheds together. Further, progressive watershed management would include estuaries and coastal resources, including fisheries and coral reefs, which in many cases are highly dependant on fresh water and nutrients (or toxins) collected from watersheds and delivered by rivers.

Community Participation

Community engagement and local participation is a key component of establishing an integrated water management strategy. Traditional, top-down management strategies often promote a narrow range of technical and policy solutions that do not reflect the nuances of a local situation. Such a model is based on the assumption that practices are universally applicable and that what works in one place will work in another. In practice, local techniques for water management are replaced rather than supplemented (Johnson et al. 2001). Issues associated with local natural resources are often more clearly and easily identified by the local community. The creation of an open and participatory framework gives communities an outlet to communicate indigenous knowledge, preventing the implementation of ineffective practices. Furthermore, involvement in the management of natural resources may foster community empowerment and capacity building, which can further strengthen sustainable solutions.

It is widely believed that community-based solutions have greater longevity than top-down approaches as these solutions involve stakeholders and incorporate local interests (Riley et. al 2001, WSSCC 2003, UNESCO-WWAP 2003). In one example, a group of fifty women in El Hormiguero, Columbia formed a "Women's Committee" to clean up their poverty-stricken town. When an outbreak of cholera finally persuaded politicians to address the needs of the town, the Women's Committee led the way. In conjunction with the Water and Sanitation Institute *CIVARA* from a nearby university, the people of El Hormiguero helped in the planning, design, decision-making, building, and ultimately management of an entire new system of pipes and wells. The community was grateful to have water finally piped into their homes and continues to pay for maintaining the system (WSSCC 2003). Such solutions are longer-lasting not only because the design better suits the needs of the community, but also because community members feel more ownership of the process because of their added input into the design and implementation phase.

The Water Supply and Sanitation Collaborative Council (WSSCC) (2003) concludes:

"The participatory approach to water and sanitation program[s] begins with locally viable plans drawn up with communities themselves; with their organizations and their resources; with consideration for their present struggles and coping strategies; and with recognition for the obstacles they currently encounter. As the WSSCC has long argued, it is not only increasing access to water and sanitation but increasing access to the management of water and sanitation that will determine whether lasting progress is made."

Gender Equality

Involving both women and men in managing water resources is widely viewed as an entry point for sustainable development and promoting greater societal goals such

as gender equality, poverty alleviation, and human rights (Brewster 2004). Social and cultural norms create and reinforce gender roles that often result in differences in practices relating to the use of water resources (Faure 2003). The social roles assigned to men and women significantly shape people's access to, use of and control over natural resources. Differences in gender roles mean that men and women often have different needs and priorities and benefit differently from natural resource use, technology development, and resource management (Brewster 2004). The fact that collecting water in developing nations, often the job of women, can take up to five hours a day and involve walks of ten miles with heavy loads is a case in point. (Water Aid 2004, World Bank 2003).

Women have contributed significantly to environment management. Most notably, women have mobilized themselves around grassroots solutions to improve their access to water and other natural resources (Schreiner et al. 2004). One example is the "Water for Food" movement in South Africa that seeks to mobilize and support the poorest women in rural areas to improve their access to and control over water infrastructure and the skills to use water productively. "Training in micro-level land and water management design, organic fertilization and pest management, as well as food processing allows women to produce food for their families, and thus save the money otherwise expended on buying food. Making the most of their creativity to invest in the natural resources surrounding them brings women new confidence and pride in providing for their own lives and that of their dependents" (Schreiner et al. 2004). Women have mobilized themselves to come up with grassroots solutions to improve their access to water and other natural resources. These creative local strategies can be used to develop low-cost sustainable community-based systems to maintain resources.

Although women have demonstrated a proclivity toward environmental stewardship (consider, for example of the work of Nobel Prize winner Wangari Maathi), women largely remain an untapped resource in developing resource management policies. Adopting a gender-sensitive approach to natural resources management can lead to a higher degree of environmental sustainability, protection of the resources, effectiveness of projects, and women's empowerment and gender equality (Brewster 2004). Reevaluating existing gender roles and expanding the role of women may lead to innovative technical approaches as well as longer-term issues such as change management, building community decision making and leadership skills, and improving consultation processes that will undoubtedly lead to sustainable solutions (Faure 2003).

Small Steps Lead to Big Rewards

Effective IWRM requires coordination between projects and sectors, between governments, nongovernmental organizations, the private sector, and academic institutions, between central governments and local citizens, and between traditional and modern ideas (Ünver 2001). This level of integration is difficult even for

developed countries with robust regulatory institutions and sound governance practices. Implementing IWRM frameworks in developing nations, therefore, will take a great deal of time, patience, and resources. Still, small-scale projects institutionalizing IWRM principles and implemented at several different levels will ultimately lead toward positive results not only for effective water management, but also for broader development of participatory and strong democratic institutions.

Programs and projects promoting water-based development can act as catalysts for broader economic, social, and environmental development. For example, water-based poverty reduction strategies aimed at the poor but involving cooperative efforts between agricultural, health, and environmental ministries can promote greater coordination between these ministries on other issues. Such partnerships can also be fostered between international and local NGOs, community organizations, international organizations, and national governments. In Turkey, the Greater Anatolia Project (GAP) was formed to support sustainable development by focusing on themes of environmental protection, gender issues, and the preservation of cultural assets as well as developing water infrastructure for agricultural and industrial production. As a result, the GAP Regional Development Administration (GAPRDA), the government agency that oversees the GAP process, works with Turkish Development Bank, the Chambers of Commerce and Industry, the Ministry of Culture, the United Nations Development Program, the Packard Humanities Group (a US-based organization devoted to conservation of historical sites), and local community-based women's centers. At the women's centers, women and girls can receive health care services and gain skills in areas such as maternal and child health, hygiene, nutrition, home economics, and income generation (such as handicrafts, computer operation and greenhouses, etc.) (Ünver 2001). While GAP is cited as an exemplary program, the cooperation and coordination that it has implemented can be replicated across the world on smaller scales.

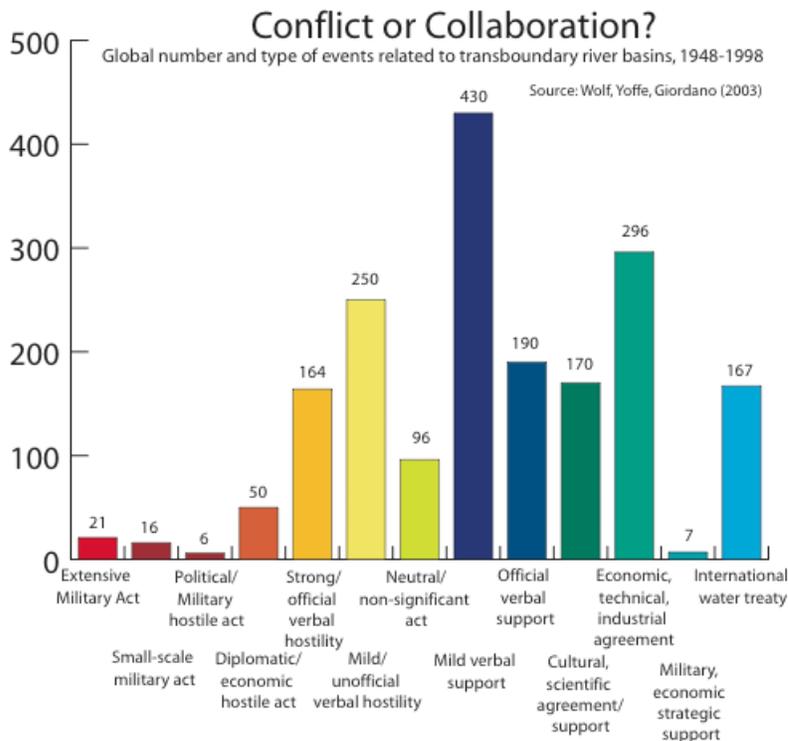
Building up alliances and improving the cooperation and coordination between sectors, community groups, governments, NGOs, and international organizations can occur at any level and at any scale if the political will is present. Traditional ideas of gender roles and power hierarchies may act as obstacles for broader implementation of IWRM principles, but can also provide ready-made networks for communicating with stakeholders (Ünver 2001). Corruption and low levels of education may also impede large-scale implementation, but capacity-building and education programs conducted at a local level may be more effective in combating these barriers and provide a base for future expansion (Pigram 2001, Ribot 2002). Local, community-based solutions are founded in the principles of community organization. The WSSCC (2003) notes that new approaches to water and sanitation programs must "embrace communities becoming organized not only for independent action but also to demand fairness, accountability, and competent service from their political representatives." The WSSCC's report, *Listening*, cites many examples of how

impoverished communities that initiated water and sanitation projects develop a sense of pride, newfound hope, and greater involvement in other areas of development or government. In a Nairobi slum called Kianda, a community organization that began with thirty people to collect garbage and build drains grew into a 300-person strong organization that is actively engaged in running a clinic and water kiosks as well as continuing to build drains and community toilets. Returning to the town of El Hormiguero, the original Women's Committee started electing women onto the official Council for Community Action that had largely ignored the needs of the community. At the urging of the Women's Committee, the Council began exploring projects such as paving the roads (WSSCC 2003). At least at the anecdotal level, water projects not only support broader economic development, but also initiate social and political development that could prove to be the foundations for a more democratic, less corrupt, and more responsive government.

Cooperative efforts organized around sustainable water management can also fortify or improve cross-border relationships. Transboundary stakeholder dialogues on water management can build trust and serve as an avenue for dialogue along official or unofficial (Track II) lines. This foundation can then grow into cooperation in other areas that may be more inflammatory between the parties or between states with little experience of cooperation (Carius, Dabelko, and Wolf 2004). Examples of such peacemaking or peacekeeping water initiatives include the "Picnic Table Talks" between Jordan and Israel, Mekong Committee, Indus River Commission, cooperation in the Caucasus over the Kura-Araks basin, and the just-started expert-to-expert collaboration along the Tigris and Euphrates Rivers.

In short, IWRM strategies require a certain level of institutional development and stability. In the absence of this base, smaller scale projects aimed at institutional capacity-building, incorporating IWRM principles, and conducted at all levels from the central government down to the community level, will ultimately result in the development of open, participatory frameworks not only for water management, but for other areas of governance as well.

Figure 16: Water has been a more often unifying than dividing force.



Diverse, Multi-Institutional and Integrated Solutions

Many of the challenges facing the world today, from water scarcity to HIV/AIDS to terrorism, are too vast and too complex to be addressed by any single institution. The global water crisis is no exception. The formation of diverse and multi-institutional partnerships is increasingly recognized as pivotal to the development of sustainable solutions. The varying competencies of government agencies, research and development laboratories, international organizations, non-governmental organizations, the private sector, and academic institutions can all provide specific expertise in addressing water challenges in situations across the globe, but no single organization can effectively address these challenges without the support and cooperation of the others. Partnerships allow participatory institutions to evaluate one another's comparative advantage and to structure cooperation that leverages each partner's strengths. Furthermore, partnerships are a vehicle through which institutions can explore linkages between previously disparate ways of thinking. These new relationships facilitate a shift away from compartmentalized thinking and present opportunities for intellectual engagement that subsequently breeds innovation. "Partnerships are particularly important in a global world where traditional boundaries between what is seen as public versus private responsibilities have become increasingly blurred, and where challenges such as the management of water resources extend beyond national and political boundaries" (Dossal and Fanzo 2004)

From Local Solutions to Global Partnerships

Productive partnerships can form at any level and involve any number or type of organizations. A compelling example of a multi-institutional partnership is the Safe Drinking Water Alliance, a strategic public-private collaboration that brings together governmental agencies, academia, and the private sector, among others, to develop innovative approaches for ensuring the safety of household water intended for human consumption. Each participant in the Alliance has specialized knowledge: the U.S. Agency for International Development is the lead implementer of U.S. foreign assistance programs; Johns Hopkins Bloomberg School of Public Health/Center for Communication Programs is a leader in the field of strategic health communications; Population Service International is a non-profit organization specializing in social marketing programs for health; CARE is an independent humanitarian organization with extensive experience with developmental and emergency water, sanitation, and hygiene promotion; and Procter & Gamble (P&G) is one of the world's largest consumer products companies developing healthcare technologies for both the developed and developing world.

These institutions have joined forces to leverage their respective expertise and resources to better understand the behaviors and motivations for choosing particular technologies for treating household water, share the knowledge gained, and identify opportunities for scaling up successful efforts to ensure safe drinking water. P&G has developed a new low-cost product, PuR, that purifies, clarifies, and disinfects water using technology and single-dose packaging that has been tested and found to be effective in improving water quality and preventing disease at the household level in developing countries. The Alliance will test the acceptance of P&G's water treatment product using various approaches tailored to meet a specific country's needs. It is anticipated that using these

"But partnerships can be a really key tool for building trust among partners and different types of groups in particular, so I think the U.S. could be particularly involved in helping to build that trust; using dialogue sessions, using round tables, whatever it may be in terms of mechanisms that can help build that trust."

*-Karin M. Krchnak, Fmr. Council for Sustainable Development
CSIS-SNL Global Water Futures Conference 2005*

"[T]he private sector can certainly not do it all. We don't have the knowledge or the capacity that we would need in public health. And for many new interventions, reaching people in the developing world requires a public help intervention, public health education, so partnerships are absolutely necessary."

*-Greg Allgood, Procter & Gamble
CSIS-SNL Global Water Futures Conference 2005*

Finding 7: Sustainable strategies must include diverse and multi-institutional partnerships. *No single government agency, non-governmental organization, corporation, international organization, or academic institution can provide all the required expertise or coordinate a sufficiently integrated response to meet the nature and scope of the challenge we face. Partnerships across social organizations are necessary for both developing and implementing sustainable solutions.*

technologies in combination with behavior change strategies will help to ensure that safe water practices are sustained at the household level over the long term.

The Coca-Cola Company has elevated the strategic priority of water in its operations and the surrounding communities (Reilly and Babbit 2005). It has surveyed 850 facilities in over 200 countries to document and consider water issues. Many of its projects are small-scale, such as the distribution of safe water storage tanks to families, or have involved environmentally friendly decisions at plants, such as collecting rainwater. These technologies are in turn often shared with local communities and governments. Coca Cola has also begun working with conservation groups to preserve and restore watershed areas around the globe. All of this serves to maintain the image of Coca Cola, and to build rapport with local communities by helping to solve one of their greatest problems. Through these actions, Coca-Cola becomes an active member of the community. Such strategies are increasingly important for corporations to consider, as the backlash against globalization and multinational corporations continue in many parts of the world.

Transboundary Water Management

The need for multi-institutional cooperation and integration is most evident in the management of transboundary water resources, which includes surface water and groundwater resources with watersheds or basins that span more than one nation-state. These water resources can form international borders or cross intra-national (e.g., regional or provincial) boundaries. The nature of transboundary water resources to indiscriminately cross political borders undoubtedly complicates the development of effective water resources management. Transboundary groundwater resources have not yet become points of contention in most places around the world, partly because of the difficulty associated with accurate characterization of them. As water resources become more scarce, conflict of groundwater resources will likely become more common – and will demand new technological and policy level approaches.

Rivers currently present one of the greatest management challenges. Across the planet, 260 rivers cross or constitute international borders. River basins cover almost half of the world's land surface and are home to about 40 percent of the world's population (Sadoff and Grey 2002). As such, countries sharing international watersheds face a two-dimensional problem: the first is to manage the water resource at a whole-basin or watershed scale; the second is to share the resource internationally. The management of shared watersheds thus requires the riparian countries to transcend both sectoral and geographical boundaries.

This is no easy task. Shared water resources often create some degree of tension among the societies that they bind. These tensions, and their responses, are bundled with many other factors—historic, cultural, environmental, and economic—that impact relations between neighboring nations (Sadoff and Grey 2002). Fully

unbundling water's role from the complex dynamics of relationships between states is not possible. Control of water resources is inextricably entwined with economic opportunity, national security, society and culture (Sadoff and Grey 2002). In the context of these bundled dynamics, watersheds can become a powerful catalyst for cooperation or conflict. Given the inherent challenges and potential for conflict, multi-institutional partnerships are essential to the creation of international legal and institutional instruments that can lead to the effective management of shared water resources.

The Euphrates-Tigris Initiative for Cooperation (ETIC) is an innovative non-governmental approach to promoting international cooperation related to water management—in this case of two river basins located in one of the most volatile regions on Earth (CSIS Global Strategy Institute 2005). Specifically, ETIC seeks cooperation between scholars in Turkey, Syria and Iraq to conduct dialogue and formulate technical, social, economic and environmental solutions to sharing the water resources between the three major riparian nations. The dialog takes place in a setting that is de-politicized, avoiding the typical “hydro-nationalism” that comes with discussing these shared waters. The goal of the model is to expand the successes of the GAP model, and to diffuse tensions over the resources through shared benefits with the recognition of comparative advantage in each country.

Cooperation across borders in the sustainable management of a transboundary water resource can generate benefits of multiple types, although the potential sum of these benefits will vary greatly in different basins (Sadoff and Grey 2002). Cooperative watershed-wide environmental management can bring benefits to resource uses and users across the spectrum by taking the necessary measures to ensure a healthy ecosystem. Such management can increase the quality, available quantity, and the economic productivity of water resources through the optimization of water uses, easing tensions among differing agendas.

International, transboundary data and information exchange at various levels is currently taking place in large and small river basins all over the globe, including the Danube, Indus, Jordan, Mekong, Nile, Rhine, and Rio Grande basins (Chenoweth and Feitelson 2001), the Kura and Araks basins of the South Caucasus (N. Kekelidze, National Academy of Sciences, Republic of Georgia, personal communication), and the Syr Darya and Amu Darya basins of Central Asia (Barber et al. 2004). Goals for these efforts range from simply opening communication channels for transboundary data sharing to transboundary collaboration on collecting data, building shared databases and models, and collaboration on management.

Cooperation in the management and development of international rivers may contribute to political processes and institutional capacities that themselves open the door to other collective actions, enabling cross-border cooperation beyond the water resources (Sadoff and Grey 2002). Cooperation over water resources may facilitate

broader economic growth and regional integration that can generate benefits even in apparently unrelated sectors—as is hoped through ETIC with the Tigris and Euphrates basins. Improved water basin management can increase the productivity of a river system, which may then generate additional opportunities in other sectors through forward linkages in the economy. The easing of tensions among riparian states may also enable cooperative ventures unrelated to water that would not have been feasible under strained relations. Thus, progress in cooperation on shared river management can enable and catalyze benefits beyond the resource more directly through forward linkages in the economy and less directly through diminished tensions and improved relationships. Cooperation on transboundary water resources is an ideal course of action as it will lead to better management and development of the resource itself, and, in many cases, it may also promote economic integration and regional security.

Water Economics

The World Water Council has estimated that to meet global water supply and sanitation demands, investments in water infrastructure need to increase from the current annual level of \$75 billion to \$180 billion (Cosgrove and Rijsberman 2000). This enormous investment gap undoubtedly poses a significant challenge and will demand innovative thinking and multi-institutional cooperation. The development and long-term sustainability of the necessary infrastructure will require the identification of additional sources of financing and the introduction of market principles such as appropriate water pricing mechanisms, or private sector participation.

Broadening the Financial Base for Water

Official development assistance is the logical place to start when thinking of ways to expand financial resources to address global water challenges. Currently, water supply and sanitation projects account for approximately 4-6 percent of all bi-lateral or multi-lateral assistance, averaging \$4.5 billion each year. Of this amount, over half is given in the form of loans (Benn 2003). There is no doubt that ODA investment in water infrastructure could be expanded, particularly given the strategic importance to water to development goals and broader economic and political stability. Investment in environmental infrastructure in general is lagging in most of the developing world. The percentage of total lending that environmental projects represent in the portfolios of multi-lateral and domestic development banks is below 10 percent, in the single digits, confirming the insufficient response from the financial institutions (Rodriguez 2004). Water infrastructure projects are commonly viewed as environment-related development, which may explain why such a relatively small fraction of ODA is earmarked for such projects. Conceptualizing the provision of safe drinking water and adequate sanitation as a development objective broader than those usually considered as environmental

objectives may elevate water infrastructure projects to a greater priority in lending agendas (Rodriguez 2004).

Expanding available financing methods to include new, innovative approaches will further boost available financial resources and benefit both the lending country or institution and borrowing country. Such new approaches include municipal bond issuance, public-private partnerships, revolving fund models, and the creation of enterprise development funds focused on water issues. Securing alternative forms of financing not only provides for abundant funds at affordable terms and conditions, but may also directly reward and foster financial aptitude, efficiency, and good governance (Rodriguez 2004). By supporting capacity building in these areas—financial aptitude, efficiency, managerial practices, accountability—international financial institutions will play a key role in ensuring the success of these new, alternative forms of financing.

Water Pricing Reforms

Expanding investment will help alleviate many of the world's water challenges, but long-term sustainability is contingent on formulating robust water pricing models. Across the planet, water is sold to consumers for below actual cost. Tariffs fail to cover the most basic costs associated with delivering water services. The revenue collected for water frequently falls short of the cost of daily operation, preventing public utilities from timely infrastructure maintenance, improvement, and expansion. In some settings, subsidization has led to inefficient water use for low-value purposes. Without an adequate pricing mechanism, consumers have no incentive to use water more efficiently, as they receive no signal indicating its relative value on the market. If water service providers are unable to recover the costs to adequately fund their operation, systems will inevitably deteriorate and the quality of service will suffer. This deterioration of

Finding 8: New ways of investing in, pricing and valuing water can provide powerful solutions.

A serious funding gap exists between projected financial needs and current trends in spending on water projects. International lending institutions and official development assistance should be leveraged to generate more in-country capital. Private-sector involvement offers a largely untapped source of investment, leadership, knowledge, and innovation, and must be mobilized. Difficulties in valuation of water and inadequate economic indicators obfuscate the role sustainable water resources play in economies. A participatory governance structure, strong institutions, clear regulatory frameworks, and better valuation methods will all support the development of new, innovative modes for financing improvements and expansion of water infrastructure.

"I certainly would argue that you'd see an improved investment and cost recovery with a regulatory framework, market-based pricing."
-Janice Beecher, Michigan State University
CSIS-SNL Global Water Futures Conference 2005

"We're going to need lots of money to be sure, but transparency, functioning utilities, dispute resolution mechanisms, project development skills and other attributes are essential."
-Gordon Binder, Aqua International Partners
CSIS-SNL Global Water Futures

water systems can be seen worldwide, particularly in developing countries, and partially explains the exorbitant funding needed.

In light of these challenges, many scholars and policymakers have proposed the price of water be rationalized, allowing costs of development and delivery to be passed to users. The Dublin Principles laid out in the 1996 International Conference on Water and Environment were the first to argue that the application of robust economic principles would improve allocation and enhance the quality of water resources. The introduction of water pricing reforms gives rise to fundamental and healthy changes in consumer behavior. Prices that reflect costs undoubtedly encourage greater efficiencies as consumers are given an indicator of the economic value of the resource. Additionally, rational water prices are instrumental in the generation of adequate revenues for the operation, maintenance, and expansion of water systems.

Research on the price elasticity of water demand supports the implementation of rational water pricing schemes. The consensus is that domestic and industrial demands are inelastic, but agricultural demands are responsive to changes in water prices. This should come as no surprise as the agricultural sector is characterized by low efficiency rates and high subsidies. Domestic and industrial users often pay over one hundred times as much per unit as agricultural users (Cosgrove and Rijsberman 2003). Introducing higher, more rational pricing schemes to farmers could provide the incentive for some of the water-saving measures discussed in the section above and provide utility companies with the capital and incentive to improve infrastructure. A downside to the application of this incentive might be the agglomeration of smaller farms into larger farms, the loss of farm jobs leading to more migration to the cities, the increasing industrialization and corporatization of agriculture, and increases in food prices that affect the poor and possibly entire economies.

However, private sector participation is contingent upon the implementation of a more aggressive pricing structure. The most efficient firms would have no interest in managing a water utility unless they could recover their capital expenditures and achieve a reasonable return on their investment.

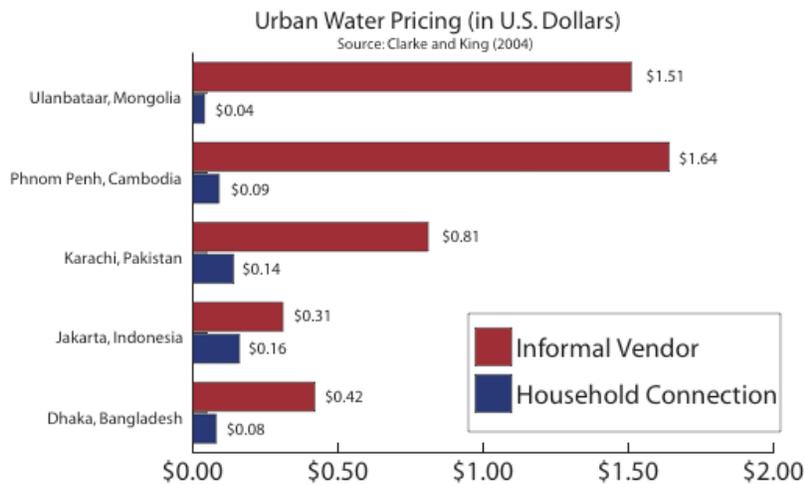
Private Sector Participation

In recent years, private sector participation has been introduced into a number of water markets around the world, based on the belief that the private sector can deliver growth and efficiency more effectively than the public sector. This is rooted in the assumption that the private sector can assist in securing the necessary funding, can provide managerial support, and will be able to apply its scientific and technical expertise. The increased presence of the private sector in the provision of water and sanitation, however, has been met with intense criticism. Concerns surrounding private sector participation are rooted in the perceived irreconcilable

difference between the guiding principles of private firms and the public interest. Central to the argument is the notion that commercial enterprises are not designed to provide public services to all consumers on an equitable basis. Market principles imply provision of services is based on ability to pay, which does not fair well for poor people. As such, poor consumers frequently end up without adequate services. Yet, time and again it has been shown that state-run enterprises in any sector are less inefficient than private sector counterparts. New models may increasingly fuse public-private partnerships, or seek to prevent virtual monopolies.

Concerns have been raised that lower income groups will be disproportionately affected by increased water prices. One way to facilitate the smooth transition to a privatized water utility is to ensure affordable and accessible water for vulnerable segments of society. Affordability becomes the most significant social issue for pricing policies because lower income households will inevitably pay a higher relative proportion of their income for water services than higher income households. The OECD (2002) proposes two measures to alleviate some of this burden: income support and tariff-related structures. With income support, individual customers are given assistance to pay their water bills through income assistance, vouchers, rebates and discounts, bill re-phasing or easier payment plans, and arrears forgiveness. Tariff-related structures keep bills low for certain groups through progressive tariffs. The first "block" of users are offered free or very low prices for "basic" water use and each subsequent block pays prices increasingly closer to market values and up to added social costs for "discretionary" use such as swimming pools (OECD 2002). In this way, governments and corporations can work together to achieve their independent goals through collective action. Governments ensure access through regulatory frameworks, while corporations are still able to meet their cost-recovery model.

Figure 17: What measures will make water services both affordable and available to the poor?



Are Developing Countries Ready?

The implementation of market principles and the involvement of the private sector are viewed as a means to overcome the significant gap in water infrastructure. However, these introductions are a point of contention, fueling the philosophical debate over the dual character of water as both a human right and an economic commodity.

There is a growing realization that water must be treated as an economic good in order to generate the appropriate funding and infrastructure to meet the ambitious Millennium Development on water and the World Summit goals on sanitation. However, perhaps more than any other resource, water demands a social and moral context given humanity's absolute dependence on this non-substitutable resource. Further, the cultural and symbolic importance of water is dramatically illustrated by its universal use in the traditions and ceremonies of the world's regions. While the debate over the value of water will continue to be hotly contested, it has become apparent that the development of sustainable strategies in the provision of clean water and adequate sanitation will require a balance to be struck between water as a social and economic good.

Beyond this debate, there are many other reasons over which developing countries express concerns over privatization or changing the economic framework applied to water. There is a concern that the poor will be excluded if rich individuals or companies are allowed to buy up all the rights and establish monopolies on a universally required resource. Some fear that the few who stand to gain from the current system may oppose its change. Others express a concern that small-scale farmers, either in desperation or in ignorance, will sell their rights for quick cash and lose their livelihoods. Finally, the high costs of setting up the new legal, regulatory and institutional frameworks necessary for ensuring privatization strategies or

changing economic frameworks effective are a disincentive for governments to institute change (Pigram 2001). All of these concerns emphasize the importance of strong institutions and open decision making processes—as well as the difficulty of transition.

Section Three: Integrating Policy and Technology

Both policy and technology solutions will be critical to solving the global imbalance of water supply and demand. Problems of water scarcity are often a function of policymakers not devoting enough financial, political, or human capital. Institutional capacities are too weak, regulatory frameworks are too vague, or investors too shy to expand and improve water supply and sanitation infrastructure. On the other hand, technologies are often too expensive, too energy intensive, or too complex to deploy in regions with limited capacities and resources. In some settings, simpler, less expensive technologies might be appropriate for meeting immediate needs, while planning and implementation of larger scale solutions are implemented. However, policies promoting both the short-term and long-term solutions and their integration are widely lacking. Reconciling the gaps between policy and technology will help solve many regional water scarcity issues.

Innovations in both policy and technology will serve to close the gap between the two. Some experts argue that there is no need to create new technologies to address water challenges across the world, because current levels of technology are sufficient and only need to be better distributed through new and innovative changes in policy. However, breakthroughs in technology that change the economics or environmental impacts of water supply, distribution, and treatment processes would make the adoption of certain policies less politically risky for policymakers. In looking forward, the most innovative approaches will reflect four considerations: (1) the linkages between policy and technology, (2) the need to specifically tailor solutions to the local situation, (3) the relationships between water, agriculture, and energy, and (4) the importance of capacity building for effective implementation of both policy and technology solution.

The Link between Policy and Technology

Perhaps the first and most important innovation in approaches to solving regional and global water resource challenges will be in the comprehensive integration of policy and technology. Shifts in policy approaches that include new strategies, new funding, new regulations, or new educational campaigns will all benefit from a better understanding of current and future technologies. In turn, effective and sustained research, development and implementation of new technologies depend on policy frameworks informed by and designed for current and future technological capabilities. Linking policy and technology more systematically will have positive effects on both.

Finding 9: Innovations in policy and technology must be tightly linked. *Innovations in policy can lead to important developments in technology, and, likewise, innovations in technology can lead to important developments in policy. Institutions must realize the synergies made possible by integrating policy and technology.*

For the purposes of this paper, technology is defined as the totality of the means employed to provide objects necessary for human sustenance and comfort (Mish 1988). Innovation in technology has many dimensions which can be applied across several spectrums, from low-tech to high tech, from local to national to international, from water treatment to water delivery to water management. In fact, innovation can stem from methods for moving the application of one technology up or down any of these scales. In very generic terms, technological “innovation” includes the following:

Scientific innovation leading to the creation of new, cutting-edge technologies;

New combinations and applications of existing technologies;

New engineering, manufacturing and distribution techniques using knowledge and other resources from across the range of stakeholder interests;

New approaches for technical capacity building, training, and education that will lead to regional ownership of solutions and the integration of technological and social systems.

“But it seems to me that any strategic global effort on water needs to include support for programs that involve the use of science and technology to better assess and understand what we’ve got, and that’s particularly true within the case of trans-boundary aquifers.”

*-Senator Jeff Bingaman
CSIS-SNL Global Water Futures
Conference 2005*

“[Y]ou need a management super-structure which is congenial to new technology, and not just the tried-and-true approaches that we heard so much about in the water sector.”

*-Hank Habicht, GETF
CSIS-SNL Global Water Futures
Conference 2005*

The term “water policy” refers to the frameworks that governments and institutions put into place in order to facilitate, monitor, and govern water management. Some measure of good governance practices, meaning “creating and enforcing a regulatory and fiscal framework that ensures honest expenditures of public funds and transparency in operation with public participation in decision making” (Hecht 2004), is necessary to uphold this framework. Innovative policy approaches could take the form of the following:

New financing models for official development assistance and private sector participation for the development of infrastructure;

Initiatives that would encourage good governance practices;

Partnerships between governments, private corporations, nongovernmental organizations, international organizations, and local citizens groups;

Regulatory frameworks that would encourage efficiency and innovation;

Programs that would scale-up local approaches proven to be effective;

Education campaigns that would alter perceptions about the importance of water and sanitation.

A wide gap exists between technology and policymaking at the local, regional and global levels. Communication between the people who set the policies, develop new technologies and implement new solutions must be regularized and strengthened to bridge this gap. There is a corresponding need for greater cross-fertilization of ideas and approaches and more integrated planning. In order to reach the economies of scale necessary for effectively addressing global water challenges, innovative solutions through the coordination of policy and technology will be necessary.

Figure 19: Water technologies and policies as they apply to water supply, demand, and management in no particular order.

Category	Technology	Policy
Supply augmentation	<p>Water harvesting through rainwater collection</p> <p>Micro-pollutant removal (e.g., arsenic) through filtration or chemical processes</p> <p>Disinfection: filtration, distillation, pasteurization, killing bacteria with ultra-violet light, others</p> <p>Desalination: distillation, reverse osmosis, capacitive de-ionization, etc.</p> <p>Advanced sewage treatment</p> <p>"Produced" water (from fossil fuel extraction) treatment and use</p> <p>Cloud seeding</p>	<p>Prioritize and institutionalize water and sanitation at national and international level</p> <p>Link water and sanitation with development strategies</p> <p>Create water management plans to expand and maintain water and sanitation infrastructure</p> <p>Protect the poorest through subsidies, increasing block tariffs, grants, providing adequate housing, improving security of tenure, and other incentives to expand coverage</p> <p>Improve governance and management practices of water utilities</p> <p>Ensure international economic environment is conducive to raising water investments in developing countries</p> <p>Mobilize additional international resources</p> <p>Ensure development assistance is going to areas of greatest need</p> <p>Strengthen coordination among donors</p> <p>Build public-private partnerships</p> <p>Devolve power from the center</p> <p>Strengthen capacities of communities and community groups for raising financial resources, water resource management, and provide sanitation</p> <p>Rehabilitate and protect water-based ecosystems to improve supply and quality</p> <p>Facilitate technology transfer and capacity building</p> <p>Engage women in planning, development, implementation, and evaluation</p>
Demand reduction	<p>Native and natural landscaping, such as xeriscaping</p> <p>Low flow household and industrial appliances</p> <p>Improved pumping and distribution infrastructure and subsystems (more efficient, with less water and energy loss)</p> <p>Domestic and industrial water efficiencies, re-use and recycling</p> <p>Coupled multi-use and treated water re-use (industrial, power generation, agricultural, municipal/domestic grey water)</p> <p>Improved irrigation technologies and agricultural practices (e.g., laser-leveling of terrain to reduce runoff, soil moisture and crop evapotranspiration monitoring coupled with irrigation scheduling, greenhouse agriculture, etc.)</p> <p>Bio-engineering of salt- and drought-tolerant, economically viable agricultural crops</p> <p>Artificial recharge of aquifers</p> <p>Evaporation suppression at reservoirs through application of micro-thin surface layers</p>	<p>Rehabilitate and maintain water conveyance systems in urban and rural areas</p> <p>Provide low-cost financing and technical support for use of more efficient technologies and practices</p> <p>Rationalize water tariffs to provide economic incentives for more efficient water use</p> <p>Raise awareness through education and advertising campaigns</p> <p>Invest in research and development of new technologies to improve efficiencies</p> <p>Facilitate technology transfer and capacity building</p>
Management	<p>In situ, real-time monitoring and data collection</p> <p>Standardized, whole-basin, transboundary data collection on surface and groundwater volumes, flow rates and quality</p> <p>Whole-basin shared tabular and GIS databases</p> <p>Collaborative, multi-stakeholder decision support modeling</p> <p>Water banking, water leasing</p>	<p>Develop indicators to monitor progress</p> <p>Establish and support databases, including baseline data</p> <p>Establish and rehabilitate monitoring networks</p> <p>Establish linkages between global, regional, and national networks and initiatives</p> <p>Provide for follow-up within existing intergovernmental processes</p> <p>Utilize traditional and indigenous knowledge</p> <p>Include women and marginalized populations</p> <p>Devise flexible land policies to facilitate cost-effective and productive land use</p>

Source: Sandia National Laboratories, 2005; Commission on Sustainable Development, "User-Friendly Matrix of the Chair's IPM Summary," 2005

Thinking Globally, Acting Locally

Effectively addressing the world's water issues will require getting the right mixture of technology and policy for each specific regional situation. Geography, hydrology, climate, political structure, institutional capacities, types of industries, agricultural practices, and financial resources, among others, together create a separate and distinct set of water issues for every region on the planet. Each of these situations—whether the problems are water scarcity, lack of storage capacity, poor water quality, mismanagement or over-consumption—requires a differentiated approach. Because local knowledge and buy-in are so important to effectively solving water problems, planning and development efforts widely distributed across jurisdictional, geographic, bureaucratic economic and social scales will be crucial for long-term sustainability.

Taking stock of the many different technological and policy-level approaches is a useful exercise for better planning a U.S. policy approach, and such an approach has been used in several forums. Most of these attempts have looked at either policy approaches or technology approaches, but few have integrated the two. Two examples from the UN Commission on Sustainable Development and the UN Millennium Project are exhibited in Appendix A. All of the approaches categorize the problems and identify a range of solutions demonstrating the full scale of solutions available—from high tech to low tech, from large scale to small scale, and from broad and complex to highly specific.

The combinations of potential policy and technology tools and approaches for different water scarcity situations around the globe are almost countless. The most important technological approaches

Finding 10: Solutions must be specifically tailored to the socioeconomic, political and geographic conditions of a region. *Solutions to water scarcity and water quality problems are different for different regions and for different socioeconomic and demographic groups within regions. Solutions must therefore be designed to meet the specific kinds of challenges presented by different socioeconomic, climatic, geographic and geopolitical conditions.*

"Bottom line is there are ways, there are alternatives, and they don't all cost a fortune. They don't all take a lot of time. Some may be short term, some may be long term, but the important factor is to choose the right solution for the right situation that will ultimately be sustainable and reduce the disease burden in that community as quickly as possible. Then other factors can come in later, economic development and so forth."

*-Joseph Cotruvo, J. Cotruvo and Associates
CSIS-SNL Global Water Futures Conference 2005*

"[T]he right mix [of community participation and supporting institutions' involvement] depends on the problem and the location, but we need to have governments, financial institutions of all kinds, and we need the kind of local capacity-building that we have heard a lot about here."

*-Hank Habicht, GETF
CSIS-SNL Global Water Futures Conference 2005*

that can be applied at various scales, and some of the ways in which the technologies and different policy approaches can complement each other in different settings are described in the pages below. This is not meant to be an exhaustive treatment, but it should serve to set some structure and bounds to the argument, and will hopefully plant the seed for more imaginative combinations constructed by others in the future.

Stated most simply, there are four ways to resolve regional and global freshwater problems: supply augmentation, demand reduction, improved management, or some combination thereof. Supply augmentation technologies produce “new” water, such as desalination, but also include treatment technologies that bring impaired waters back into the supply chain. Demand reduction technologies include numerous conservation approaches spanning domestic, agricultural and industrial uses. Improved management technologies provide approaches for optimizing among supply augmentation and demand reduction, as well as social, political and economic values. An array of the three different kinds of technologies either currently available or appearing on the horizon is described in Figure 19. More detail on each category is given below.

Supply Augmentation

Augmenting water supplies includes expanding access to safe drinking water through water treatment, improving and expanding wastewater treatment, and expanding the actual physical supplies of water through water storage, transport, and desalination. Together, these approaches will increase the number of people with access to safe water as well as ensure enough water for human pursuits and the environment.

Drinking Water Treatment

Out of all the global water challenges and their effects on human health, economic and political stability, providing safe, clean drinking water could deliver the most immediate and far-reaching impact (Mintz et al. 2001). However, the technological and policy needs across the developing and developed world are extremely varied. In developing regions, lack of access to clean water leads to ongoing public health crises and reduced economic productivity. In middle-income countries, maintenance and expansion of existing infrastructure is the key need. In developed countries, efforts in water treatment are moving toward meeting ever-higher public health and environmental standards, and toward significant reductions in industrial waste-related levels of micro-contaminants. Moving forward in both the developed and developing worlds requires significant commitment to research and development of technologies and policies that fit the specific needs of a wide range of diverse situations.

Many technical solutions already exist across this wide spectrum of needs. In almost all cases, limits to financial resources, human capital, and public support or coordination create barriers to implementing these solutions. This is particularly true for the expansion or rehabilitation of sanitation, water treatment and distribution networks in low and middle income countries. In urban centers, rapid population growth, further exacerbated by rural emigration, are placing ever increasing constraints on city governments to expand coverage to areas of uncontrolled growth and improve existing infrastructure. Developing rural infrastructure has traditionally been a lower priority as a result of the higher costs associated with more dispersed populations (UNESCO-WWAP 2003). Improving governance structures that could attract investment or secure financial resources for infrastructure development in such low- and middle-income countries would be one step in the right direction. Additionally, supporting community-driven solutions will foster the kind of cooperation and coordination necessary for developing sustainable infrastructure development and management solutions.

Although many large infrastructure solutions require a significant degree of policy coordination and innovation, there is still room for technical innovations that would reduce the costs of expanding or improving infrastructure. For example, ITT Industries has designed a pump that has reduced maintenance and operating costs by 30 to 50 percent (Ayers 2000). Longer-lasting, more efficient, and cheaper technologies would greatly benefit middle- and low-income countries looking to expand infrastructure to the approximately 20-30 percent of their populations lacking access to improved water supplies (World Bank 2005).

Point-of-Use Approaches

Because infrastructure development or repair at any scale can be expected to take a great deal of time and resources, the development community has turned to decentralized, low-cost, household water treatment and safe storage (HWTS) solutions as stop-gap measures that would provide safe drinking water immediately to the populations of greatest need (Lantagne et al., in press, Mintz et al. 2001). Several HWTS systems have been developed and tested across the world and can be categorized into (1) filtration, (2) disinfection, (3) flocculation/disinfection.

Filtration systems pass water in buckets or other containers through a filter made of natural materials, most often sand or ceramic (Lantagne et al., in press). These filtration systems are proven to remove bacteria and protozoa, have a long life-span, and are relatively inexpensive because they can be made from local materials. Disinfection systems rely on chemicals, typically sodium hypochlorite, to kill bacteria and some viruses, but often leave a residual taste in the water. Ultraviolet rays in solar disinfection systems (SODIS), which involves leaving clear, plastic bottles filled with low-turbidity water on a roof or rack for

six hours (if sunny) or two days (if cloudy), will inactivate protozoa cryptosporidium and giardia as well as bacteria and some viruses (Lantagne et al., in press, Mintz et al. 2001). Finally, the last type of HWTS combines a chemical coagulation step to reduce turbidity and a disinfection step. Procter and Gamble's product, PuR, uses this process. Sold in single-dose sachets containing ferrous sulfate (a flocculent) and calcium hypochlorite (a disinfectant), users add the powder to an open 10-liter bucket, stir for five minutes, wait for a period while the solid waste settles to the bottom, filters the water through a cloth to a second bucket, and finally wait for twenty minutes while the hypochlorite kills the microorganisms. In addition to removing particles, bacteria, viruses, and protozoa, PuR can also remove heavy metals, such as arsenic (Lantagne et al., in press, Greg Allgood, Director, Safe Drinking Water, Procter & Gamble, personal communication). All of these methods or combinations of the methods have been proven to reduce incidences of diarrhea and other water-related disease (Lantagne et al., in press, Mintz et al. 2001, Crump et al. 2005).

In addition to treating unsafe water, storing the water safely and changing attitudes toward water purification and sanitation will be equally important to reducing water-related sicknesses. The Centers for Disease Control (CDC) have determined that in many cases around the world, even water that is clean when distributed to centralized neighborhood locations becomes contaminated by the time it is carried home in dirty containers, or within houses where it is stored in open containers. In Zambia, for example, where water is transported mostly by hand, up to 43 percent of households use some form of an open container, which is highly susceptible to contamination. Once inside the household, approximately 700 out of 2,910 households surveyed do not use some form of lid to protect water from dirt (CDC 2003). Water storage vessels that are considered "safe" include plastic containers with tight-fitting lids, narrow mouths, and allow users to remove water by pouring through spigots rather than dipping (CDC 2001). These types of storage units prevent re-contamination that is prevalent with open buckets or other containers used for collection, transport, or storage. Safe water storage vessels are an integral part of the "Safe Water System" (SWS) created by the Centers for Disease Control and Prevention and used throughout the world (CDC 2001). Behavioral change is another key element of the Safe Water System. Switching from traditional water collection, transport, and storage methods to any of the HWTS systems takes some degree of training and behavior change (Mintz et al. 2001). In addition, changing hygiene and sanitation practices, such as washing fruits and vegetables or even hands with clean water before eating, will provide further benefits to health and well-being. Social marketing, motivational interviewing and community mobilization techniques have been employed to orchestrate these changes in behavior to complement HWTS technologies (Lantagne et al., in press).

Developing and dispersing the HWTS “hardware” is yet another barrier to providing safe drinking water to the poorest, but several innovative methods capitalizing on nongovernmental organizations, community groups, health networks, and international coalitions have been employed. International nongovernmental organizations have been involved in funding the development and dispersal of the actual physical parts of the HWTS systems—from Samaritan’s Purse, an international faith-based NGO, installing BioSand Filters to Population Service’s International’s distribution of PuR and CDC’s Safe Water System. Other NGOs have focused on supporting micro-enterprise to manufacture the filters or chemicals necessary for different systems using locally available materials. Still others have worked with government health ministries or trained local teachers, sanitarians, health officials, and community representatives to act as trainers and technicians to spread the knowledge of how the different systems work and their importance (Lantagne et Al., in press). Even universities have engaged on these issues. Dr. Susan Murcott in the Department of Civil and Environmental Engineering at MIT leads a program, “H₂O=1B,” which takes engineering students to developing countries in order to engineer water supply and treatment solutions using locally available resources (Susan Murcott, personal communication). Village level success has been widespread with these approaches; but reaching regional or national success has remained an illusive goal of point of use technologies.

In between household water treatment and safe storage systems and major infrastructure development is emerging a new brand of modular water treatment units. While similar types of units have been used by militaries and in disaster relief situations in the past, recent advances in UV filtration and reverse osmosis membranes have reduced the costs of these effective water treatment technologies to explore wider distribution. Several groups and private corporations are developing such units. Two notable organizations are exploring socially conscientious, but business oriented strategies for deploying them: WaterHealth International, a small California-based private corporation, and WaterLeaders, a non-profit organization recently formed by philanthropist Kenneth Behring. Both systems use a range of traditional and high-tech filtration and disinfection methods to reduce turbidity and remove harmful organisms from the drinking water. Each unit could be scaled for use by communities, individual households, or in emergency relief settings. In addition, WaterHealth International and WaterLeaders are operating with a semi-business model by seeking to recoup the production costs of each unit sold (WaterHealth International 2005; Robert Steiner, Executive Director, WaterLeaders, personal communication). These organizations are filling a demand for higher-quality water from communities that can pay but lack access to municipal water supplies both in rural and urban settings. The long-term sustainability of these models remains to be seen.

Wastewater Treatment

Preventing contaminants from entering water supplies in the first place is equally important as expanding water treatment and more cost effective than having to remove harmful substances from water supplies. Improving wastewater treatment technologies is essential around the world for protecting streams to which wastewater is discharged, and for maintaining surface water quality for downstream users – whether that use is for direct consumption, agriculture or industry.

Human waste is currently the single largest cause of water pollution at the global scale. Two million tons of human waste is released into streams and rivers around the world every day (UNESCO-WWAP 2003). In order to prevent the contamination of local or downstream water supplies, some form of improved sanitation—a simple pit latrine, ventilated pit latrine, pour-flush latrine, or a connection to a septic system or a public sewer and treatment facility—is necessary. This is especially true for overpopulated urban areas where untreated sewage from informal settlements and even from municipal sewage systems is released into rivers and coastal areas in close proximity to people's homes. In such areas, local, community-driven and -designed solutions are crucial for long-term sustainability. Partnerships between local community members (including women), nongovernmental organizations, community-based organizations, local governments and private contractors have been very successful in India in building public sanitation facilities in area slums (UNESCO-WWAP 2003). These projects have enjoyed long-term success because the needs and cultural viewpoints of the community were considered and the community was actively engaged in implementing and maintaining the solution. The latrines used were simple in design, but they were leveraged with the technical expertise of the private sector contractors who assisted with site placement and engineering the entire facilities.

As urban populations expand and as densities increase, sanitation practices beyond the basic latrine will be necessary to efficiently and effectively remove and treat human waste. Innovative technological approaches to wastewater treatment already being applied include waterless, vacuum toilets; two-part toilets for the separation of urine and fecal material from wastewater; and increased use of organic materials from wastewater for use as fertilizers. Some of these approaches have been experimented with in Swedish and Chinese "ecovillages." The use of various kinds of anaerobic processes for municipal wastewater treatment have shown they can yield high efficiencies with low costs

Box 6. Modularized Sewage Treatment Facilities.

A large-scale approach that could combine new technologies with new policy approaches might be found in the design, manufacturing, distribution and maintenance of modularized, single-stage, transportable sewage treatment plants. For example, a manufacturing center in New Delhi, India, could manufacture these modular plants or plant components – utilizing chemically-enhanced primary treatment (CEPT) or other technology -- for transport by truck to cities around the Himalayan region. Modular treatment plants could be implemented in series with more modules linked for higher volume treatment, and fewer modules linked for lower volumes. The manufacturing center in New Delhi could become a training center for module placement and maintenance. Regional standardization of modules could help create a broadly based operations and maintenance staff, skilled and available to work on modules across the region. This economy of scale could help overcome shortages of skilled operators for water treatment plants in developing nations noted above. Manufacturing and deployment would offer employment and other business opportunities in the region as well. Local educational institutions could develop special technical and academic curricula aimed at development of this industry. In addition, pumping and distribution systems could deliver treated wastewater to agricultural fields. All of this would require a comprehensive policy component and funding stream.

and simple maintenance, relative to more commonly used aerobic processes, and can produce biogas for heating and power generation. More research and development is required to make all of these technologies more effective and widespread (Henze et al. 1997, Jenssen 2004, Rosemarin 2004).

Technological innovations in better chemical coagulants and flocculants or breakthroughs in ways to incorporate biological processes may alter the economics of sewage treatment to make it more viable for poorer municipalities to improve their treatment. Re-exploring and improving upon older techniques, such as chemically-enhanced primary treatment (CEPT), would lead to the same end. Designing, manufacturing, distributing, and maintaining modularized, single-stage, transportable sewage treatment plants of varying sizes (see Box 6) may create opportunities for both improved sewage treatment and a new industry for developing countries.

The need for more advanced sewage treatment in developed countries is becoming increasingly evident as more sophisticated water quality monitoring and analysis projects begin to better identify the quantities of both macro and micropollutants (hydrocarbons, organics, pharmaceuticals, estrogens, etc.), and as the impact of those pollutants on both human and ecosystem health become better understood and regulated. New technologies for water treatment described above will be increasingly important in reducing urban discharge to surface water bodies.

Improved treatment of sewage discharge around the world is the single most effective way to improve surface water quality. However, sewage discharge is not the only pollutant in surface water systems. Overland runoff and seepage from cities, garbage dumps, animal feedlots and agricultural fields together

represent the largest source of surface water and groundwater pollution, and new technologies to limit their effects on water quality would have substantial, important impacts. However, the widely distributed nature of this pollution source makes it extremely difficult to treat. Also at issue are inadequate regulation, enforcement, and incentives for industry, agriculture, and municipalities to make improvements. In this case, again, technological solutions must be integrated with policy-level action.

Technologies used now to control these distributed pollution sources include riparian buffer zones of vegetation maintained along streams and riverbanks expressly to intercept and absorb contaminants in runoff. An innovative but costly approach would add water treatment systems to irrigation return flow canals for removal of herbicides, pesticides, nutrients and salts that run off from agricultural fields. Perhaps the most sensible and cost effective agricultural technologies for improving surface water quality would be those that allow more precise and conservative application of smaller concentrations of pesticides, herbicides and nutrients. Application of pesticides and herbicides from crop-dusting airplanes, for example, delivers large quantities of chemicals that have large unintended effects on non-crop vegetation, beneficial insects and animals, and surface water quality.

Storage and Large-Scale Water Transport

Improving water and wastewater treatment will have a dramatic affect on the lives of many people around the world without access to safe, clean water. However, in order to meet the growing demands of all water users, including people, agriculture, industry, and the environment, some degree of expanding water storage and large-scale water transport will be necessary. Tackling Mother Nature's unequal geographic and temporal distribution of water resources has been an enduring hurdle throughout human history, but today's challenge is to create solutions that will satisfy the needs and concerns of all users, including natural ecosystems.

Dams and water storage reservoirs represent an ancient and enduring technology. An estimated 800,000 dams of all heights and more than 45,000 large dams (greater than 15 m in height) have been built around the world for flood control, power generation, water diversions and water storage for irrigation and municipal supply. Approximately 40,000 of those large dams have been built since 1950, so many of their long-term hydrological and ecological impacts are yet to be understood (Postel and Richter 2003). The global rate of dam construction averaged 170 per year during the 1990s, down from 360 per year from 1951-1977 (Postel 1997). This decline in construction reflects in part the growing cost and increased challenge in finding sites for new dams. Further, concern over environmental impacts has increased the effort required to win approval for new dams. Important technological issues for existing dams and

reservoirs include development of improved methods for maintaining aging physical infrastructure, restoring capacity lost to siltation, preventing damage to downstream hydroecological systems, and securing dams from malevolent attacks.

Large-scale transportation of water from regions of water abundance to regions of water scarcity has been proposed, but few projects have begun or been completed. An old Soviet plan to divert Siberian rivers to the shrinking Aral Sea still lingers among some water planners in what are now the central Asian countries of the former Soviet Union. Various plans have explored moving water from Canada into arid regions of the U.S. by canal, and from Alaska to California by undersea pipeline. All these projects are estimated to produce water so costly to consumers that they have not been perceived as cost effective. Water is already moved by canal or pipeline as many as several hundred miles in the southwestern United States, and a project in Texas hopes to move up to 185 million cubic meters of water from the Ogallala Aquifer in the Texas panhandle to cities as far away as Dallas, San Antonio and El Paso. A large-scale diversion project that may still be in the planning stage aims to transfer water from the Yangtze River to the Yellow River in northern China (Postel 1997).

Box 7. Libya: Great Manmade River Project

One large-scale water transportation project, billed by some as the biggest civil engineering project in the world, is the Great Manmade River Project in Libya. This 5-phase project aims to eventually move 2 billion cubic meters of water from aquifers beneath the Sahara Desert of southern Libya to agricultural fields along coastal areas in the north. So far only the first phase of the project is complete, at a cost of \$25 billion. When operating at full capacity the phase-one efforts will deliver 700 million cubic meters annually to coastal areas (FAO 1997). The water being provided in this project has high salinities and so is useful only for agriculture. As the project has unfolded, however, doubts have been raised about whether Libya should spend so much on developing its own agriculture, rather than buying its food from more water-rich regions (Omar Salem, Chairman of the Libyan General Water Authority, personal communication, 2004).

Such large-scale infrastructure projects present many technical challenges, but the problems posed to policy makers are equally challenging. Curbing the seepage and evaporation that occurs in conveyance canals and reservoirs through surfactants, biofilms, and better liners will preserve a significant proportion of the water held in these large scale projects. The volume of water lost to evaporation from reservoirs has been estimated to exceed the global freshwater needs of industry and domestic consumption combined (Shiklomanov and Rodda 2003). Improved pumping methods and technologies will further reduce costs. However, the real costs to the environment and social upheaval associated with such large-scale projects are becoming of increasing concern for policymakers. Global outrage over environmental degradation, corruption, and mismanagement have led to greater scrutiny over proposed large dams and water transport projects. Developing large-scale infrastructure is absolutely

essential to mitigate water-related natural disasters and improve a developing country's water security. However, new projects must be done in accordance with a highly sophisticated integrated water management plan created in an open participatory framework that reflects the agricultural, industrial, social, and cultural needs of the regional stakeholders. Such criteria, increasingly enforced by international lending agencies, are difficult for developing countries with imperfect governance records to meet.

Some very important, smaller-scale technologies can serve to increase water supply and have dramatic impact on poverty relief. In South Asia, tube wells owned and maintained by groups of poor farmers are making water available for irrigation. International Development Enterprises (IDE) is a non-profit organization with offices and projects around the world that uses market principles to attack rural poverty issues. In India, IDE is facilitating the marketing of manual treadle pumps, called the "farmer's friend", which sell for \$12-25, are becoming widely used in areas with shallow groundwater, and can produce low but essential yields by anyone, including children (IDEI 2004). IDE India is also helping to develop and market low-cost bucket- and drum-based drip irrigation technologies, which are also becoming more widespread (IDEI 2004). Rainwater harvesting for irrigation and groundwater recharge is becoming increasingly important around the world with sophisticated capture systems in developed regions, and with very simple systems in developing regions.

Desalination

Desalination technologies are being considered as one of the primary technological solutions for meeting global water needs. Modern desalination technologies have applications for the purification of brackish and sea water, but they can also be effective in removing other kinds of dissolved contaminants from impaired waters. The main drawbacks in the past to desalination technologies have been that they were energy and cost intensive.

As technology has improved, the cost of desalinated water has been significantly reduced and currently ranges from approximately \$2-3 per thousand gallons for sea water purification and \$1.00 - \$1.50 for brackish and reuse water purification, depending on input water quality, plant location, and plant size (Hinkebein 2004, Ebensperger and Isley 2005). In brackish water applications, however, the removal of concentrate (highly concentrated saline waste) can substantially increase the cost of this purification (USBOR/SNL 2003). All these costs are compared to current standard drinking water treatment costs of \$0.30 to \$0.40 per thousand gallons (USBOR/SNL 2003). Currently, about 15,000 desalination plants of all sizes are in operation throughout the world (Ebensperger and Isley 2005). These plants are generally in developed countries with the economic ability to build and operate the plants, or in other regions,

island states and the arid Middle East where water is extremely precious and the energy required for power is of secondary importance.

While desalination technology has progressed significantly in the past 30 years, there are still several major areas that need to be addressed to advance its wider use. For example, 20-40 percent of desalination costs are associated with energy, so reducing energy use is an important technological innovation for advancing desalination use (Ebensperger and Isley 2005). Concentrate from desalination processes can have negative environmental effects on both coastal and inland areas where increased salinities can damage fisheries, wetlands, or other ecosystems. Therefore, as desalination applications continue to increase, concentrate and salinity management will become increasing concerns.

Five broad research and technology areas have been defined to drive the next generation of desalination research in the United States (USBOR/SNL 2003). The focus is on reducing overall treatment costs by 50 to 80 percent. This will help make desalination more competitive with other water sources. These research areas include:

- Membrane technologies that desalinate and purify water by pushing it through a semi-permeable membrane that removes contaminants;
- Thermal technologies that rely on boiling or freezing water and then capturing the purified water while the contaminants remain behind;
- Concentrate management technologies which focus on the disposal, volumetric reduction, and beneficial use of the saline byproducts of desalination;
- Reuse/recycling technologies (including membrane and alternative technologies) that can handle large contaminant loads;
- Alternative technologies that take advantage of advances in other technology areas and applying these to desalination.

These five research areas are also important to accelerate desalination applications in many international settings. Research advances are being made world wide. It is important to collaborate and coordinate efforts among countries

The value of mobile desalination plants for assisting in humanitarian disasters was demonstrated following the Asian tsunami of 2004. U.S. Navy warships with desalination capabilities were deployed to provide badly needed freshwater to victims of the disaster. Since fresh water shortages are ultimately one of the primary sources of the disease epidemics that spread through areas stricken with all types of natural and human-induced disasters, improvement in mobile desalination technologies could play a large role in future humanitarian relief efforts.

Demand Reduction

Technology can be expected to effectively expand the world's water supply for human uses, as it has done in the past. Ultimately, however, increasing pressures on supply will make demand reduction increasingly cost effective and important. The steps for reducing demand and the capacity for implementing these steps vary widely across the world. In developing regions, domestic, industrial, and agricultural water conservation is poorly developed and organized and improvements in agricultural and industrial efficiencies are the main target. In developed regions, efforts in domestic, agricultural and industrial water conservation employ ever more sophisticated and expensive approaches. In both settings, government-led policies are necessary to encourage the adoption of water-saving techniques and technologies from the most simple to the most complex.

Agricultural Efficiencies

Agriculture accounts for more than 70 percent of global water use, so it is an area in which even marginal savings can represent very large quantities of water. The highest irrigation efficiencies in the world are found in Taiwan, Israel and Japan at values from 50 to 60 percent, but efficiencies in most developing countries range from 25-45 percent (Rosegrant et al. 2002). More efficient irrigation technologies and practices can help boost food production with less water use and reduced environmental impact. Drip irrigation for the precise delivery of water to plants, soil moisture monitoring and laser-leveling of fields for preventing over watering, lining and/or covering irrigation ditches to prevent losses to seepage and evaporation, and the continued development of greenhouse/hydroponic agriculture all have the potential to improve productivity per unit of water used for many crops. Shifting from conventional surface irrigation approaches (including flood irrigation) to subsurface, drip and low-loss sprinkler technologies has increased overall water productivity by 25 percent to over 200 percent for crops as diverse as bananas, cotton, sugar cane, sweet potatoes, and food grains. Despite the potential water efficiency improvements, only about 1 percent of irrigated farm land worldwide uses precision irrigation (Gleick 2002b, Gleick 2002c). Innovation in all these areas to make application of these technologies less expensive and more widely implemented could lead to very large savings of water.

Industrial Efficiencies

Industrial usage accounts for 22 percent of global freshwater withdrawals, second only to the agricultural sector (Shiklomanov and Rodda 2003). Therefore, large reductions in overall water demand can be achieved by employing concepts of efficiency, reuse and recycling, and infrastructure modifications in the industrial sector. Manufacturing and processing equipment can be improved to require less water. Infrastructure improvements include

addition of grey water plumbing to facilitate reuse on a grand scale within individual buildings and across communities. Intel Corporation, one of the world's largest computer chip manufacturers with facilities across the globe, employs several water-intensive processes to create its products. Through maintaining what Intel staff call a strong corporate water management program, they have developed requirements for their equipment suppliers that reduce water needs, and have instituted re-use practices for up to 50 percent of the water required in some manufacturing facilities. Through these actions, Intel reports it has managed to reduce its global water requirement from more than 9 to just over 6 billion gallons annually (Frank Robinson, engineering supervisor, Intel Corp., Rio Rancho, New Mexico, USA, personal communication). Similar policy and technology improvement opportunities exist throughout industry. The role of policy will be to ensure funding to continue research and development of these often higher-cost technologies and to promulgate regulations and incentives to accelerate their acceptance in the marketplace.

Together with greater efficiencies in the agricultural sector, reduced freshwater usage in the industrial sector would greatly reduce global water demand. The relationship between these two sectors becomes intertwined in the energy sector, itself a major source of freshwater use. The subsequent energy efficiencies that will be needed within the "iron triangle" are discussed at greater length in the section to follow.

Urban Conservation

Water use practices for many urban environments with high concentrations of humans are increasingly unsustainable. With the expected growth of urbanization and megacities, demand will be significantly concentrated in many basins and ecosystems unable to provide adequate water resources while maintaining the current condition of regional groundwater, surface water, biological and environmental resources. These factors create an impetus to reduce demand from human consumption and overall municipal delivery systems in urban centers.

A discussion of municipal consumption should address both indoor and outdoor uses separately. Numerous technologies exist for reducing both kinds of municipal consumption, and many are becoming increasingly widespread. For indoor uses, low-volume toilets, urinals, showerheads, faucets, clothes washers and dishwashers are well established in markets throughout the developed world. Conservation regulations in the U.S. requiring that new homes be constructed with low-volume appliances and programs for converting appliances from the traditional to the low-volume variety have been successful in different regions (Vickers 2001). Outdoor uses in the U.S. are predominantly aimed at landscaping. In arid regions of the U.S., xeriscaping (landscaping with plants native to arid regions) has become increasingly widespread. Rainwater

harvesting from rooftops and gray-water reuse technologies are improving and becoming more widespread around the world (e.g., Öman and Bino 2004). Rainwater harvesting for water use in commercial enterprises and for aquifer recharge is also being implemented around the world (e.g., Biswas and Gupta 2004)

True innovation is required in the entire planning and architectural process for homes, businesses, and industries. New construction technology could integrate water harvesting systems into the roofing and include cisterns for storage in yards or beneath buildings. Buildings could be constructed with two plumbing systems, one for clean water leading to faucets, showers and washing machines, and one for gray water leading from the sinks, showers and washing machines to the toilets and/or landscaping. Filling toilets with good drinking water is one of the great ironies in a world of increasing water scarcity. Water from toilets can flow into constructed wetlands that decompose waste and purify water, and which provide landscaping outside. Harvested water in cisterns could feed into a grey water system. Pumping and filtering systems would be required for both the harvested water and the grey water. Most of these integrated construction innovations have been developed but are yet to be widely applied (McDonough and Braunaugh 2002, Bunn 2003, Sattler 2003). These too will benefit from policy-level decisions that create financial incentives, tax advantages, rebate programs and other initiatives to spur progress.

Delivering water for urban uses and expanding delivery networks to surrounding sub-urban and rural neighborhoods can benefit greatly from improved regional delivery technologies. "Unaccounted for water" (UFW) is a major loss term in municipal water distribution systems. (UFW is the difference between the amount of water sold and the amount of water supplied, expressed as a percentage of the amount of water supplied.) Well managed systems achieve UFW values of 10-15 percent. In developing nations the UFW values range from 39 to 52 percent (Rosegrant et al. 2002). UFW is a function of leakage from old transmission systems, poor metering and/or poor management.

Reducing those UFW numbers in developing nations generally calls for modernization of pumping and distribution systems – which could be considered more of a governance and economic problem than a technical problem. However, even low UFWs in arid regions of the world can have significant impacts on an already scarce drinking water resource. New technologies designed to monitor and detect system weaknesses (breaks, leakages) could help eliminate some water loss. These technologies already include in situ, real-time monitoring systems in early phases of development. These monitoring technologies would be linked to distribution management centers located at key nodes around the distribution system, and could allow for the quick identification and repair of system weaknesses. These same centralized monitoring

technologies can also address security issues associated with malevolent attacks on water supply and distribution systems.

Improvements to all these technologies would lead to greater volumes of conserved municipal water, but in these cases the real bottleneck is not at the technological level but at the policy level. Development of various kinds of fiscal incentives to drive the conversion to low-volume appliances, water harvesting, reuse and xeriscaping are likely to have much larger impacts on water conservation than will marginal improvements to domestic water conservation technologies. Revoking water subsidies to farmers and factories would create further economic incentives to adopt water-efficient agricultural practices. Placing a premium on rehabilitating water conveyance systems in both urban and rural areas will require a reprioritized government budgets or reorganization of the service delivery system (i.e. privatize, increase tariffs, or decrease subsidies). In turn, public education and marketing campaigns to sway the public's perception on the necessity of such measures will also be necessary. The enormity of the political will necessary to enact such changes has proven to be the most formidable barrier in their implementation.

Management Technologies

In a world of increasing population, increasing resource consumption, and decreasing resource availability, wise management of remaining resources becomes increasingly important. Management of resources was once command-and-control oriented, and disregarded the dynamic and unpredictable variation in resource availability over years and decades. Current understanding of ecosystem processes and resource dynamics make it clear that management of resource systems must be flexible and adaptive (Gunderson et al. 1995, van den Belt 2004). Broad, multi-disciplinary stakeholder involvement is essential to understanding all aspects, values and relationships in the complex and dynamic resource systems that must be maintained and managed to ensure enough water of an adequate quality is available for all users and the environment.

Information is critical to effective management. Technologies that provide the necessary information can be broken into two categories—those that collect and convey the data, and those that aid in interpreting the data. The first category, called “monitoring and data collection,” describes innovative technical and social approaches to monitoring and data collection across regional and international boundaries, and among international partners. The second category, called “data interpretation and systems modeling,” describes innovative social and technical approaches for the development of decision support tools, such as geographic information systems (GIS) and computer simulation tools. Case studies

described below will show how components from both categories can be woven together to provide a complete and effective water management plan.

An important technological innovation spanning all these components and categories will be the electronic networking and communications systems that allow stakeholders from various parts of a watershed or from various parts of the world to communicate, share information, and work together in real time. Many parts of these kinds of systems already exist (e.g., teleconferencing and remote computer operation) but the integration of all these kinds of systems and the increased capacity to collaborate technically over long distances will offer great advantages.

Monitoring and Data Collection

The list of variables important for monitoring is extensive and includes river discharge, reservoir volumes, snow pack, evaporative losses, seepage losses, human consumptive uses, groundwater levels, water quality, and sediment load, among others. New technologies that can measure or forecast the amount of water available, measure water quality, or facilitate the sharing of information over time and distance are continuing to be developed and are already being employed in some regions. Such technologies include faster and cheaper laboratory analytical methods, in-situ, real-time monitoring technologies, and Doppler acoustic technologies. Research and development efforts into improved monitoring technologies are yielding micro-chemical and nano-electrode real-time sensors, aimed chiefly at volatile organics and regulated contaminants and intended for monitoring of drinking and industrial process water distribution systems. These technologies, however, could also be applied to surface water sources in the future. All of these technologies are currently expensive, and reduced costs will be necessary for widespread application.

In addition to surface water monitoring, understanding and observing groundwater supplies will be equally important. Groundwater is estimated to provide about 50 percent of the world's drinking water, 40 percent of the water used for industry, and 20 percent of water used in irrigated agriculture (UNESCO-WWAP 2003). Still, capabilities for characterizing those underground water resources generally lag behind the capabilities applied to surface waters. Again, technologies exist, but they need comprehensive, integrated implementation. Large-scale projects must be initiated to map and characterize groundwater resources, especially those along international borders where future conflict of water resources is a risk.

Faster transmission of the data collected on surface water and groundwater supplies or quality will assist in more efficient and equitable water management. Today's advances in communications technologies push developments in data transmission forward. Many kinds of water resource data are being transmitted

from in-situ, remote monitoring stations by telephone or satellite networks. These systems depend upon measurements made at automated field stations which are then transmitted automatically by cell phone to centralized locations or by radio to orbiting satellites. The international Global Terrestrial Observing System (GTOS) and the U.S. National Oceanic and Atmospheric Geostationary Operational Environmental Satellite (GOES) system are two networks dedicated to collecting and distributing worldwide remote-sensing spatial data on water and other resources. One of the problems created by these data transmission systems can be the sheer volume of data produced. Technology advances are required for more rapid, complete and inexpensive processing and interpretation of the remotely sensed data. The international nature of these distribution networks make the data universally available, but in many developing regions shortages in human capacities, technology hardware, and financial resources combine to make these technologies and information inaccessible.

Innovation and development of all these technologies will be important in the future for more accurate measurement of surface water supplies, water treaty compliance and resource management and planning. However, both historical and cross-border gaps in datasets limit water managers' capacities for effectively and efficiently monitoring and managing water supplies.

Long-term data on water resources are essential for understanding historic and current impacts of human activities on water resources. In addition, historical data are important for projecting future trajectories of water resources from different scenarios of future population growth, consumption patterns and management strategies (See Smith et al. 1987, Spahr and Winn 1997, Passell et al. 2005). In most regions of the world, long-term data sets are patchy or unavailable. Datasets that do exist were often collected at different times, by different organizations, using different collection and analytical methods. Consequently, information on a single river or aquifer that crosses jurisdictional or political boundaries is not easily comparable. Further complicating cross-border management, data often are not shared among transboundary resource managers, either for political reasons or simply because data sharing mechanisms and agreements are not in place.

The U.S. Geological Survey (USGS) has pioneered and mastered long-term, whole-basin, remote data gathering technologies for the United States, including real-time river discharge, but similar programs in other countries and regions around the world are rare. Pioneering whole-basin, international, transboundary data collection and data sharing projects currently exists among four Central Asian nations in the Aral Sea Basin (Passell et al. 2002, Barber et al. 2005; <http://ironside.sandia.gov/Central/centralasia.html>), and among three nations in the South Caucasus (Armen Saghatelyan, National Academy of Sciences, Republic of Armenia, personal communication; <http://www.kura-araks->

natosfp.org/). These projects include stakeholder institutions from all the partner countries; standardized monitoring, data collection and analytical technologies; and data sharing websites open to project partners and the public. These projects allow whole-basin water quantity and quality analyses never possible before. As in many cases, technologies available for these kinds of projects around the world are available, but without comprehensive policy initiatives the projects themselves are few and far between.

Data interpretation and systems modeling

Some of the most important technological innovations are and will be those that help turn data into knowledge. Various kinds of computer-based modeling and simulation approaches allow users to simulate the outcomes of different future management scenarios by projecting sensitivities on variables such as conservation approaches, population growth, and consumption rates. The mathematical models use historic data and/or empirical studies to offer projections about the amount of withdrawals that a groundwater or surface water resource can sustain in the future. These models are also useful for integrating into a single analytical tool the understanding of structural characteristics spread among various scientists and stakeholders. For example, urban consumption requires understanding drawn from an array of professionals—city managers, geologists, ecologists, irrigation experts—and a model can unify the knowledge distributed among them all.

Several variations of these kinds of tools are becoming increasingly important in water resources management. Very sophisticated groundwater flow and global circulation models are now being developed by the USGS and others, and represent one set of tools and understanding. Geographic information systems (GIS) models allow the storage, organization and complex manipulation of very large spatial data sets, and represent another set of tools and another kind of understanding. System dynamics models allow integration of these different kinds of tools and understanding into a single model that can unify it all.

There are several ways in which computer models have historically been and are currently being used in water-management decision making. First, detailed models of physical systems were originally the domain of technical experts who used them to generate data and information used for purely academic or commercial purposes, or to deliver that information to decision makers. In addition, empirical models based on expert opinion have been used to engage the public in dialogue by helping to explain complex issues and/or to demonstrate the outcome of some potential decision (Stave 2003).

Finally, some models now are being developed collaboratively among technical experts, decision-makers and stakeholders in order to reach collaborative resource management decisions (Costanza and Ruth 1998, van den Belt 2004).

This process includes creating broad and diverse teams of stakeholders with interests in and knowledge of the resource. As part of this process these stakeholders work together to define the problem, assess historical data and patterns, formulate possible sets of solutions, and work together to build models that simulate the implementation of those solutions and their future impact on the resource. The collaborative approach engages stakeholders, builds trust in the resulting models among stakeholders, and helps assure that the models will be more fully used in decision making. Figures 10a and 10b show the interface of a collaborative model developed at Sandia National Laboratories (Tidwell et al. 2004).

Figure 18. Examples of interfaces from Sandia National Laboratories Middle Rio Grande Basin Water Management Model

Figure 18a

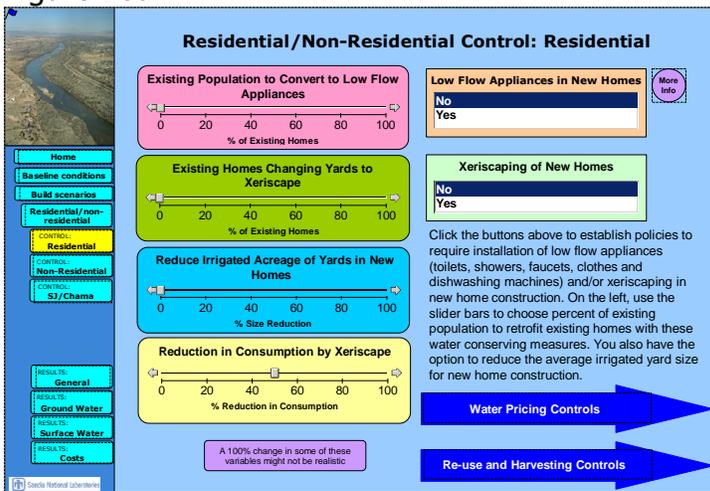
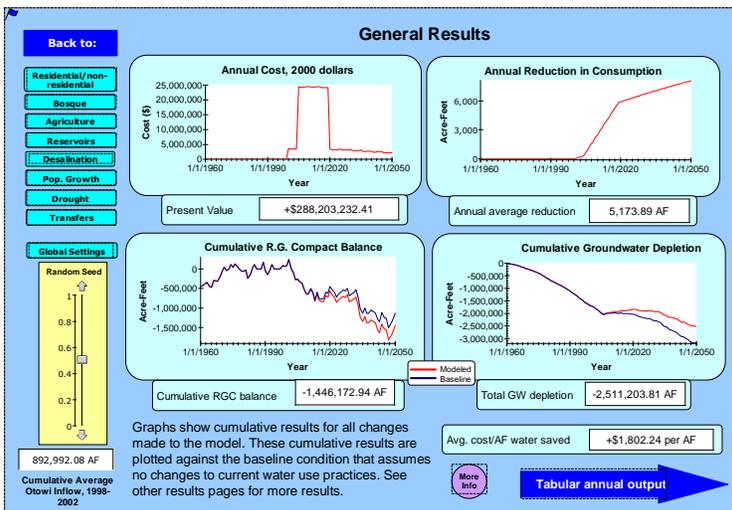


Figure 18B



18A: Example of slider bar and button controls used to simulate future water consumption scenarios in Sandia National Laboratories Middle Rio Grande Basin Water Management Model. 18B: example of graphic output used to describe results of model simulations. Model shown here runs at an annual timestep from 1960 to 2050. Model runs take less than 10 seconds. Model simulation from 1960 to 2000 is calibrated to historic data, and projection to the future is based probabilistically on historic data.

An important technological innovation in these modeling approaches will be to integrate system dynamics modeling with GIS technologies, so that GIS data can be used easily in systems dynamics models and so that system dynamics output – the consequences of future management scenarios -- can be visualized in a GIS. Continued opportunities exist for considerable and valuable improvements to more conventional types of groundwater flow modeling, surface water modeling for fate and transport of contaminants and sediments, and evapotranspiration modeling. Very important contributions could be made from improvements to climate modeling aimed specifically at helping us understand what impacts global climate change will have on water supply and sustainability. Innovations could also be valuable for allowing data from real-time sensors to be transmitted by satellite and then automatically input to models, allowing for a kind of real-time modeling of resource dynamics.

Water, Energy and Agriculture

The linkages between water, energy, and agriculture will provide further opportunities for innovative policy and technology responses. Further exploring the linkages, improving efficiencies, and integrating management plans among the three would serve to expand water supplies and mitigate water demand.

At every stage of the water production and delivery cycle, significant amounts of energy are needed to extract, pump, transport, purify, and distribute water to all users, including farmers (Malik 2002). Between 2 and 3 percent of the world's energy consumption is used to pump and treat water for urban residents and industry. The Alliance to Save Energy, through its "Watergy" project, has identified several easily implemented strategies to water supply and treatment that saves an average of 25 percent of a municipality's energy budget. By adjusting pressure control, flow control, peak load reduction, and the timing of pump or motor starts and stops through automatic sensors, telemetry, and supervisory control and data acquisition (SCADA), municipalities

Finding 11: Planning for and management of water, energy and agriculture must be strongly integrated.

Important interdependencies exist among water, agriculture and energy production, all of which are critical to human welfare and economic development. Technologies and policies focused on improving efficiencies in food production, power generation, or water use should take into consideration and leverage this interconnectedness for maximum impact.

were able to save hundreds of thousands of dollars they could then use to expand and improve water infrastructure (Alliance to Save Energy 2003). By simply improving the way existing pumps work together, the city of Indore, India was able to save \$35,000 within three months without investing a single rupee (Alliance to Save Energy 2002). In Zagreb, Croatia, variable speed controllers developed by ITT industries lowered municipal energy costs and water usage by as much as 60 percent (Ayers 2001).

"Quite simply, if these two sectors can improve the use of water, there will be more water for others. Worldwide, manufacturing wastes water and consumes large amounts of water by pollution. Agriculture uses 70 percent of the world's water. We must have the will power to look at the waste in these two areas and initiate improvements."
-Steven R. Lorranger, ITT Industries
CSIS-SNL Global Water Futures
Conference 2005

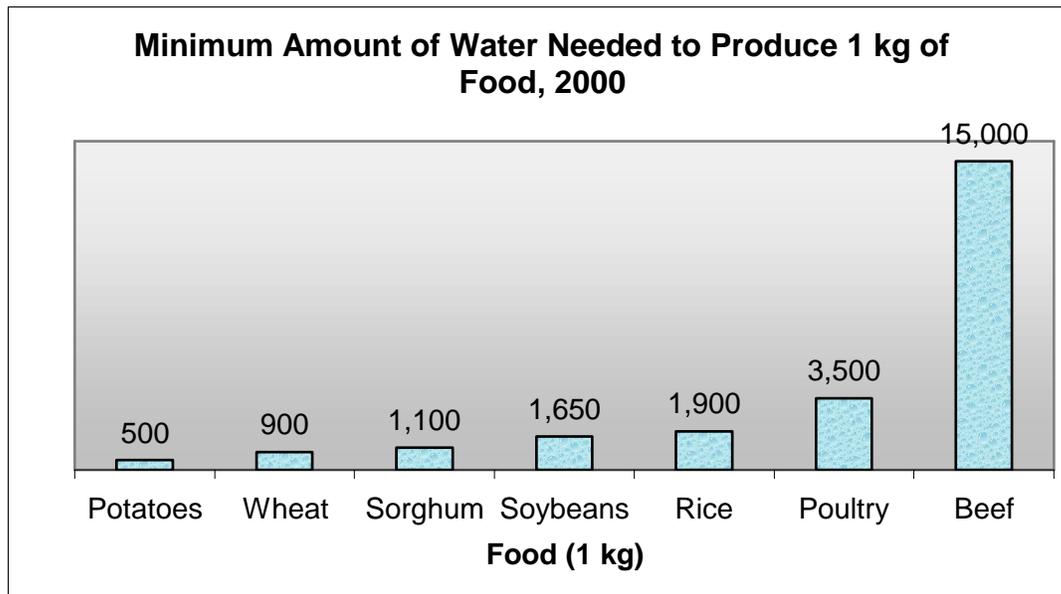
At the same time, water frequently plays an important role in power generation. Most often water is used to generate electricity, through hydroelectric dams, or to cool equipment in thermoelectric power plants. Again, statistics from the U.S. maybe be instructive. According to the U.S. Department of Energy's National Energy Technology Laboratory, 39 percent of freshwater withdrawals in the United States are used in power generation, second only to agriculture. In more practical terms, each kilowatt-hour of electricity requires about 25 gallons of water to produce (E&WR 2005). Increased deployment of non-water-using renewable energy technologies for power generation, such as wind and solar, would greatly reduce overall water demand. If growth in power generation over the next century will come through new fossil-burning plants, new cooling technologies using far less water will be required. Such technologies are currently being developed for regions of the world that are already under severe water limitations. Dry cooling units, requiring almost no water, are already in operation, and will likely grow considerably in use with greater technological development.

In no other area do these two resources play a more vital role than in the agricultural sector. Irrigation activities have consistently consumed large amounts of energy and water. In India, the agricultural/irrigation sector accounts for approximately 80 percent of total water use and 30 percent of the total electricity consumed (Malik 2002); however, it provides the *smallest* fraction of total revenue from electricity generation and distribution. The World Bank estimates that current losses in the Indian power sector amount to approximately \$5 billion per year and are growing rapidly (USAID: India 2003). Californians see 43 percent of their captured rainfall and 85 percent of the state's developed water resources go towards agricultural uses (Lofman et al. 2002).

From California to India to South Asia, farmers' consumption of large quantities of water and electricity are enabled through a variety of subsidy programs and flat rate tariffs. These benefits provide discounted water and/or electricity

services for agricultural activities – benefits that have led to over consumption of both resources (IWMI-Tata WPP 2003). In California, farmers pay \$137 less per acre-foot of water compared to the fee for basic municipal services (Lofman et al. 2002). Meanwhile, it is estimated that India’s electricity board loses \$5.3 billion per year in potential usage fees that could be charged to farmers. Instead, India’s subsidy and flat tariff programs prohibit the energy sector from recovering these losses, which are estimated to grow at 26 percent per year (IWMI-Tata WPP 2003). Changes in agricultural subsidy programs must also be weighed against increasing costs of food production.

Figure 19: Agriculture requires significant quantities of water



Source: Clarke and King 2004

Some analysts contend that pursuit of food production self-sufficiency in water-stressed regions is misguided and unsustainable. These experts promote the concept of “virtual water” trade as a more promising approach for relieving pressure on the world’s water resources (Allan 1998, Allan 2003, Chapagain and Hoekstra 2003a, b and c, Chapagain and Hoekstra 2004a and b). Virtual water trade entails establishing a global food trading system that is built around the idea that production of water-intensive, lower-value food crops (e.g. cereal grains) should be done in water-rich countries to offset or replace production in water-stressed countries and regions. The water-stressed countries would then consciously choose to import such food products (and the “virtual water” that they represent) and put their own limited water resources to a higher economic and/or more conservative purpose, in the form of higher-value agriculture or other industrial uses.

On a per gallon basis the economic value of goods produced through water use is greatest for high end manufacturing (drugs, computer chips, etc.), and human health benefits derived through providing clean municipal drinking water. Agriculture, as a productive enterprise, generally produces the lowest 'water-normalized' economic value. However, agricultural food production and related bio-products are fundamental to the economic growth and stability of nations worldwide. For water-sparse regions, altering agricultural practices and engaging in "virtual water" trade may be a consideration to allow for more productive use of limited water supplies. The effects to energy demand have not been explored.

The risks of weakened food security, food sovereignty, and economic growth associated with changing policies and food trade patterns to conserve water must be evaluated. Including virtual water as a policy option for both importing and producing countries requires a deep understanding of the impact and interactions on the local social, economic, environmental, and cultural situation. Import of virtual water can relieve pressure on the importing nations' resources, but can also have consequences in the producing nations (e.g., overexploitation of local land and water resources). This is an area where technical innovation could contribute to broader and more accurate collaborative information gathering, information management, modeling, simulation, interdependency analyses, and decision support. Real implementation of this approach may require highly innovative international institutional water trading mechanisms, similar to CO₂ and other pollution trading mechanisms.

In today's world, the fates of the water, energy and agriculture sectors have become deeply entangled. Examining the production and delivery practices, as well as the underlying assumptions, for each sector provides an excellent opportunity to solve the challenges within each sector while preserving valuable natural resources. Indeed, a full understanding of the nexus between water, energy and agriculture is vital to improving the management of all three sectors, securing global energy, food, and water supplies for a growing world, and capitalizing on innovative and sustainable solutions.

Robust Capacity Building

While all of the policy and technology solutions mentioned thus far are essential for addressing global water challenges right now, none will be sustainable in the long run if the indigenous capacities of the target countries are insufficient to maintain, revise, and develop new solutions. To achieve sustainable water management, technical, financial, managerial, and human resources capacities will need to be strengthened in both central governments and local communities, in both individuals and institutions.

In the past, the transfer of technology from developed countries to developing regions has proven to be effective for as long as the technology lasts. However, as the well becomes contaminated, as the pump breaks, as the reservoir behind the dam becomes silted, the technology is rendered useless or even harmful without the indigenous technical know-how to repair or re-think the solution (Pigram 2001). Furthermore, imported technologies often require imported parts or materials for maintenance, driving up the maintenance costs. Technical capacities to design, implement and maintain new technological solutions will be key in creating sustainable approaches (UN Millennium Project 2005). Such capacities could be built through exchanges, but developing indigenous institutional strengths and capabilities will be more practical and more sustainable in the long run. In addition, improving local technical capacities in low-income areas will allow local people to develop innovative technologies and service-delivery systems designed with their specific needs and capabilities in mind (Lenton et al. 2005; WSSCC 2003). Such local innovations will serve to expand water supply and sanitation coverage.

Finding 12: Robust capacity building is essential. *Results achieved around the world by existing technical aid and infrastructure development programs can be vastly improved with greater efforts to support regional capacity building. These efforts should be aimed at regional education, political and economic innovation and technical expansion sufficient for long-term operation and maintenance by local, indigenous institutions. They must also include both technical and institutional capacity-building.*

"I believe that a sustainable solution to the problem will only come when society can adequately develop their own resources to sustain their own economy."
 -Tom Hinkebein, Sandia National Laboratories
 CSIS-SNL Global Water Futures Conference 2005

A strong commitment to robust capacity building in developing nations may be one of the most important changes that must occur in the current approach to ODA made by U.S. funding agencies and international banks. Current approaches most often use ODA or international loans to fund U.S. companies as they provide infrastructure and/or services, but not explicitly develop a robust program in capacity building that will leave indigenous populations not only with the new infrastructure but with the long term capability to sustain it and even repeat it themselves (WSSCC 2003).

Finding new and innovative funding sources will also require developing local capacities. As official development assistance declines and the costs associated with expanding access to water and sanitation and maintaining aging systems mount, national, regional and local governments will have to develop and sustain alternative methods of financing. Expanding the capacities of local officials in budgeting, accounting and basic revenue management as well as facilitating the

transition of regional and national authorities from managers to overseers will facilitate this process and allow local authorities to more actively engage local communities to develop community-based solutions (Lenton et al. 2005). Improving regulatory frameworks that would attract more investment also implies improving the capacities of the regulators who uphold the frameworks. Corruption can be a significant barrier to these steps, but may be contained or reduced by the same kinds of efforts (Pigram 2001).

Identifying the right technological approaches and securing the financial resources for implementation and maintenance should be done within the context of an integrated water resources management plan. The development and continuation of this planning requires fairly sophisticated understandings of natural and human-induced effects on water supply and quality. Advanced technical capacities in monitoring, assessing, and planning are essential. However, as important are the human resources engaged in the process. Expanding policymakers' and managers' understanding of the importance localized, community-based needs and solutions play in developing sustainable solutions will ensure more voices are heard throughout the planning process. The UN Millennium Project (Lenton et al. 2005) even proposes the incorporation of "social intermediation professionals" who are trained in listening and incorporating the concerns and suggestions of women, the poor, and other often disenfranchised groups. As the report notes, women "often have different criteria to evaluate the adequacy, equity, timeliness, convenience, and quality of various interventions (Lenton et al. 2005)." Beyond the technical knowledge of planning and managing water supplies, improving understandings and capacities for communication with community groups, the poor, women, and other disenfranchised groups will be as important in reaching sustainable solutions.

Building capacities of people and institutions is clearly a necessary step in developing sustainable solutions. Education is the most obvious route to building up individual's abilities and knowledge. Several programs involving governments, universities, international organizations, and nongovernmental organizations have initiated education exchanges and training courses aimed at the middle tier to top tier government officials and water managers. However, such capacity building must be conducted with the same considerations of local situations and needs as other policy and technology solutions (Pigram 2001). Successful examples from other developing countries, such as Brazil, Turkey, and Mexico, should be the model rather than Australia or the United States where the methods may only lead to unachievable goals or outcomes (Pigram 2001).

However, to truly achieve robust capacity building and reach the poorest segments of society with the greatest needs, the aim should be knowledge that creates more knowledge—educating one person and then providing the incentives and opportunities for that person to educate others. Organizations

engaged in household water treatment and safe storage initiatives have learned the value of training trainers that spread knowledge of how to use certain products and social marketing schemes that promote safe hygiene and sanitation practices (Lantagne et al., in print). In this way, knowledge and understanding is dispersed allowing more input from local knowledge.

Section Four: U.S. Foreign Policy and Global Water Challenges

Traditionally, the United States has regarded the serious humanitarian challenges associated with water access and quality as simply one of many variables in its overall foreign assistance policies. That limited approach is no longer functional. U.S. policymakers can no longer regard the challenge of international water exclusively through the lens of economic development and foreign assistance. While there can be little doubt that there is a critical humanitarian dimension to the challenges of water access and quality—present and future—U.S. policymakers must also recognize that growing water dislocations suggest the potential for instability and conflict. Therefore, Washington must also regard water as an element integral to promoting and realizing its broader national interests and foreign policy agenda.

In short, for the various reasons set out in the previous sections of this White Paper, water has evolved into a strategic interest for the United States. It is a key factor not only in U.S. humanitarian policies and economic development strategies, but also in U.S. security, political, economic, and commercial interests in vital regions across the planet.

The overriding challenge confronting U.S. leaders is threefold. First, they must consider geopolitical realities and reformulate their vision of how water impacts U.S. foreign policy. Second, they must retool the organizational structures and processes by which international water policy is formulated and implemented, reflecting the new, “strategic” nature of water. Third, they must work to strengthen cooperation with elements outside the U.S. Government—including foreign counterparts, international organizations, international development institutions, the private sector, and non-governmental organizations—to develop solutions commensurate with the magnitude of the water challenges facing the world.

This section will (1) explore the linkages between global water problems and U.S. strategic interests, (2) examine current U.S. actions to solve global water problems, and (3) identify possible approaches for the future.

Water as a U.S. strategic interest

Access to clean water is fundamental to breaking the poverty cycle. It is a matter of life and death for billions of people around the world. Water-borne diseases afflict populations around the globe and take an enormous human toll. The need to gather water reduces productivity and keeps children out of schools. Lack of sanitation facilities in schools keeps young girls from attending past

certain ages. The unconnected urban poor are made to pay up to twenty times as much for water supplies trucked into their neighborhoods.

Providing safe, clean, reliable, affordable drinking water gives the poorest in the world a platform on which to improve their lives. Without this platform, any other poverty-reducing measure attempted through agriculture, education, gender equality, will not reach its full potential because the people it targets will not have the time, energy, or health to participate. For years, these humanitarian and economic development arguments have been the basis for U.S. international programs on water. They are every bit as compelling today as they were decades ago. The case will be even more compelling in the future.

Now, the challenge to U.S. policymakers is to embrace the broader dimensions of the global strategic challenge that is water. In light of the global trends in water that were outlined in earlier sections, it is clear that water scarcity, water quality, and water management will affect almost every major U.S. strategic priority in every key region of the world. Addressing the world's water needs will go well beyond humanitarian and economic development interests. Virtually every major U.S. foreign policy objective—promoting stability and security, reducing extremist violence, democracy building, post-conflict stabilization and reconstruction, poverty reduction, meeting the U.N. Millennium Development Goals, combating HIV/AIDS, promoting bilateral and multilateral relationships—will be contingent to some extent on how well the challenge of global water can be addressed. In addition, water issues will assume ever sharper definition in regions that are strategically important to the United States—the Middle East and North Africa, East Asia, and South Asia, among others.

Finding 13: Water can be a powerful and effective foreign policy tool. *Effective engagement of international water issues can significantly support many U.S. foreign strategic objectives. Strategies to address geopolitical and regional instabilities, economic development, humanitarian concerns and democracy are more likely to succeed by elevating the issue of water.*

"The awareness raised by the tsunami can and I hope will be a catalyst for all of us to invest in rehabilitating, developing, and strengthening water and sanitation systems globally, and in the process reaffirming and strengthening our commitments as responsible community partners"
-Jeff Seabright, *The Coca-Cola Company*
CSIS-SNL Global Water Futures Conference 2005

"Water and governance may tell us a lot more. I think we should connect democracy and institution capacity building into water aid programs. I think the way we do water, being transparent, accountable and participatory, will do more as a learning ground for building the habits and experience of democracy."
-Jerome Delli Priscoli, *US Army Corp of Engineers*
CSIS-SNL Global Water Futures Conference 2005

Mobilizing development of water infrastructure goes hand in hand with promoting peace and political stability. Many regions strategically important to the United States are facing serious internal water crises and/or cross border tensions over shared water resources. Experts have noted the importance of water to reaching a lasting peace between Israel and Palestine. One observer stated, "Israeli strategists always name control over water sources as one critical factor making necessary, in their view, retention of at least a part of the occupied Arab territories. Within this framework, 'water security' concerns are mentioned in one go with traditional military security and the issue of Jewish settlements (Libiszewski 1995)." In the same region, tensions between Israel, Jordan, Syria, and Lebanon often heat up over the waters of the Jordan River. Israel's former Water Commissioner Meir Ben Meir has warned, "I can promise that if there is not sufficient water in our region, if there is scarcity of water, if people remain thirsty for water, then we shall doubtless face war (Welsh 2000).

In Asia, India and China both face serious internal and cross-border pressures over water resources. Both countries have experienced domestic uprisings in the last few years spurred by citizens' displeasure over water management or water quality issues. Additionally, tensions over the Indus River remain high between India and Pakistan, despite the long-standing agreement on water sharing that many hail as the only successful agreement ever concluded between the countries. Thailand and Vietnam are increasingly displeased with China's unilateralist moves at damming the Mekong River.

While the debate over water as a potential cause for war in the future continues, the fact remains that water scarcity and poor water quality are destabilizing forces that impact both economic and social stability. Facilitating cooperative arrangements over shared water resources not only diminishes these disruptive forces but also provides avenues for cooperation and political development in other spheres.

Supporting other countries in the development of integrated strategies for managing water is important to fostering peace and stability between and within countries. This is particularly true as trends in population and natural resource consumption increase pressure on governance structures and economic systems. Because water is so integral to human life, many strategies to promote economic development or humanitarian relief (e.g., poverty reduction or HIV/AIDS relief) cannot be achieved without a recognized water component. Water projects can also strengthen democracy-building projects in areas where such projects are not well-received by fostering inclusive decision making and management processes at a local scale. For example, in Afghanistan local village-level water management traditions and structures have remained in tact through the Taliban's rule and post-conflict period (Pain 2004). However, tensions between villages could be mitigated by strengthening the district-level management

institutions, which could also lead toward improved communication, coordination, and greater accountability within municipalities. Afghanistan lends just one case study, but a review of most post-conflict or unstable areas will demonstrate that water should be a key component in any short-term or long-term regional stabilization and reconstruction effort.

Water also has significant implications for U.S. international economic policy. It is a key driver of economic stability and prosperity in a number of important regions across the world. As previously discussed, water has structural linkages with the agricultural, energy and industrial/manufacturing sectors and its availability and quality are therefore critical to prospects for growth and stability. Conversely, if the challenge of access and quality worsens, water could contribute to economic and financial instability and uncertainty. Development of water systems also represents a potential commercial interest for the United States. By virtue of their technologies and innovations, a number of U.S.-domiciled companies are well positioned to play an important role in addressing the global water challenge. The global water industry is valued at between \$360 billion and \$540 billion (Global Water Intelligence 2004). It is expected to grow 3.3 percent between 2005 and 2009 and 5.7 percent between 2010 and 2014 (Global Water Intelligence 2004). A stronger, forward-looking position will promote both domestic and international economic growth.

For all of these reasons, water can no longer be regarded exclusively as a function of U.S. humanitarian and foreign assistance policies. It has significant security, political, social, economic and commercial implications for U.S. interests as well. For this reason, there is a strong argument that U.S. policymakers should elevate water on the list of U.S. interests. Water has become a strategic and overarching element of U.S. international interests.

Level of U.S. Engagement

The United States has a great deal to offer in addressing global water challenges. It already commits significant amounts of money to international water projects and devotes considerable resources to developing new technologies. Both the Executive Branch and Congress have worked to increase financial resources for development assistance and technological development over the past few years. Yet, the question remains: Are we doing enough and are we taking the right approaches?

Finding 14: An integrated, comprehensive international U.S. water policy is essential:

The United States has the technical capacity, knowledge, and wealth to help relieve water scarcity problems in countries and regions around the world.

However, a lack of coordination and prioritization among all the different agencies involved in the decision making and policy implementation process has led to a largely ad hoc approach to global water issues. The United States should therefore develop a coherent, comprehensive water strategy for meeting global water challenges in order to maximize its impact and achieve broader U.S. foreign policy objectives.

First, in examining the relative resources committed to addressing global water problems, it is clear that the United States is devoting significant resources to these issues. Yet it is unclear if these commitments adequately reflect the absolute importance of water to overall development goals. Official development assistance (ODA) for water has vacillated over the past decade, mirroring overarching international efforts and campaigns to address water supply and sanitation problems across the world. For instance, ODA for water supply and sanitation dropped drastically just a few years after the UN International Drinking Water Supply and Sanitation Decade came to a close in 1990 (see Figure 20). Interest in water supply and sanitation picked up after the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg. In response, the Bush Administration committed \$970 million over three years through the United States Agency for International Development (USAID) to address the problem with the highly visible Water for the Poor Initiative (WFPI). In the first two years of the WFPI, the United States exceeded the projected three-year budget and has spent \$1.2 billion on over 100 activities related to water issues around the globe (USAID 2005).

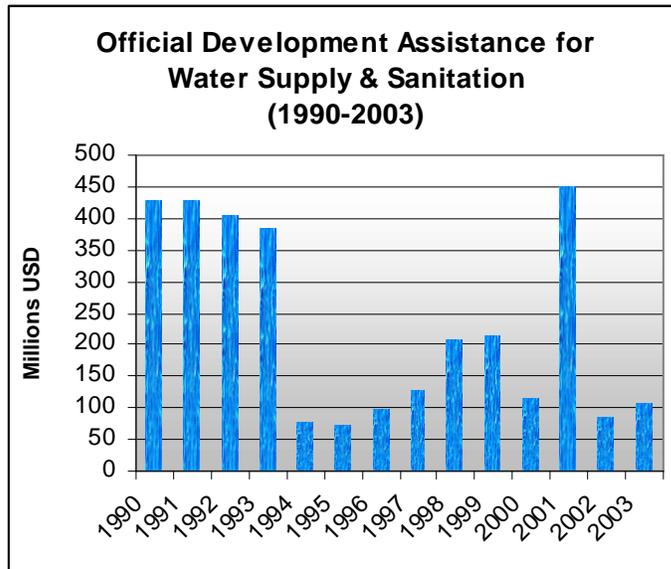
"We don't have a clear strategy...a clear strategy as to how to proceed and begin to organize an effort to deal with the set of issues that we confront. I don't think we have institutions in place...to bring about the kinds of changes with regard to water use and consumption that is needed."

*-Senator Jeff Bingaman
March 9, 2005, CSIS-SNL Global
Water Futures Conference*

"There is no single place in the US Government to get a comprehensive view of water policy and issues. There is no consortium of businesses addressing water needs and opportunities. Water must become a policy priority. It is time for a national and international expansion of commitment to the water century which provides clean, safe water, appropriately managed and conserved for the good of all."

*-Steven R. Loranger, ITT Industries
CSIS-SNL Global Water Futures
Conference 2005*

Figure 20: U.S. ODA for Water Supply and Sanitation (1990-2003)



Source: OECD, DAC Database (2003)

In comparison to other major sources of ODA, the United States has a mixed rating. From 1999 to 2001, the United States spent on average \$252 million each year (up from \$186 million for 1996-1998) on official development assistance related to water and sanitation. Out of 21 major OECD donors, it ranked third behind Japan and Germany for total amount allocated. The \$252 million, however, represented only 4 percent of total ODA, which pushed the U.S. rating down to nineteenth out of the 21 OECD countries (OECD 2003). However, these numbers only reflect allocations to water supply and sanitation projects. According to a recent GAO study, between 2000 and 2004 the United States spent approximately \$3 billion on freshwater programs abroad when desalination, flood control, irrigation, navigation, water dispute management, water conservation, and watershed protection, restoration, and management are included along with figures related to drinking water supply and water treatment projects (GAO 2005).

Figure 21: Global ODA to water supply and sanitation (1996-2001)
Ranked by annual average commitment and share in total sector-allocable aid

USD Total (millions)			%of donor total		
Country	1996-1998	1999-2001	Country	1996-1998	1999-2001
Japan	1442	999	Austria	17	18
Germany	435	318	Japan	14	14
United States	186	252	Denmark	15	13
United Kingdom	116	165	France	13	13
France	259	148	Luxembourg	4	13
Netherlands	103	75	Germany	19	11
Denmark	103	73	Italy	14	9
Spain	23	60	Finland	11	8
Austria	34	46	Spain	4	8
Australia	23	40	Ireland	7	7
Sweden	43	35	Netherlands	8	7
Norway	16	32	United Kingdom	8	7
Italy	35	29	Australia	3	6
Switzerland	25	25	Sweden	6	6
Canada	23	22	Switzerland	7	6
Belgium	12	13	Norway	4	5
Finland	18	12	Belgium	4	4
Luxembourg	2	8	Canada	4	4
Ireland	6	7	United States	6	4
Portugal	0	5	Portugal	1	3
New Zealand	1	1	New Zealand	2	2
Total DAC Countries	2906	2368	Total DAC Countries	11	9
AfDF	56	64	AfDF	10	9
AsDF	150	88	AsDF	11	8
EC		216	EC		5
IDA	323	331	IDA	6	6
IDB Sp F	46	32	IDB Sp F	9	9
Total Multilateral	575	730	Total Multilateral	7	6
Grand Total	3482	3098	Grand Total	10	8

Source: OECD DAC Database (2003)

As with virtually every other development program, more money could be devoted to official development assistance for water supply, sanitation, and infrastructure development. Certainly, as has been demonstrated, these

programs would support many of the other development goals of U.S. foreign policy. However, with today's increasing budgetary constraints and ever-tighter watch on fiscal spending, there is the risk of creating a "robbing-Peter-to-pay-Paul" phenomenon that would result from policymakers enacting unfunded mandates for government agencies to increase programming for water projects.

Several recent attempts by lawmakers to elevate water as a strategic priority of the U.S. government have fallen prey to inadequate political will. In turn, these good intentions have headed down the path of the unfunded mandate. This year, for example, Senate Majority Leader William H. Frist (R-TN) began to publicly champion the priority of international water policy for the United States on the basis of humanitarian values and national security interest. A bill co-sponsored by Senator Frist and Senate Minority Leader Harry Reid (D-NV), called the *Safe Water: Currency for Peace Act*, was introduced on March 2, 2005. The act sought to amend the Foreign Assistance Act of 1961 by formally enshrining water and sanitation issues in US foreign aid policy. The bill cleared the Senate Foreign Relations Committee within twenty-four hours, but had no funding attached to it and was later tacked onto a State Department Authorization Bill where its prospects for passage are not favorable.

There was a similar set of developments in the House of Representatives. In April 2005, Representative Earl Blumenauer (D-OR) introduced the Water for the Poor Act to the House of Representatives. The bill linked safe drinking water to poverty reduction, economic development, expanding education, gender equality, and environmental sustainability. As of June 2005 the legislation was still being considered by the House Foreign Relations Committee. While these efforts were indeed heroic, they illustrate two points: (1) global freshwater challenges are an issue around which bipartisan support can be easily mounted, and (2) White House support will be necessary to garner political willpower for concerted action.

Beyond reviewing total resource allocations, it is important to also examine how programs are developed and which regions of the world are receiving the most attention. One-third of the \$3 billion the United States spent on water-related programs abroad from 2000-2004 went to Iraq and Afghanistan during the 2002-2004 period alone. The other \$2 billion was spread "throughout the world," according to the GAO (2005) study. The U.S. Agency for International Development (USAID) has consistently been the largest spender on freshwater programs abroad, accounting for over \$331 million, or 87.5 percent of total financial support for freshwater programs abroad (excluding Afghanistan and Iraq), in 2004. Of this amount, only \$9 million, or 3 percent, went to Africa while the majority went to just three countries – Egypt, Jordan, and the West Bank/Gaza. This disparity reflects the global trend of concentrating assistance

for freshwater programs as well as competing geopolitical and security priorities within U.S. foreign policy.

The disparity in regional allocations for freshwater assistance is also, in part, due to the process by which it is dispersed and coordinated through government agencies. Eight agencies accounted for the majority of the \$2 billion spent on freshwater programs abroad—Foreign Agricultural Service (U.S. Department of Agriculture), U.S. Army Corp of Engineers (Department of Defense), Fish and Wildlife Service (Department of Interior), U.S. Department of State, African Development Foundation, National Science Foundation, U.S. Agency for International Development (USAID), and U.S. Trade Development Agency. The State Department plays the lead U.S. government agency role in water policy planning, while USAID is the lead federal agency in implementing foreign policy assistance for water and sanitation. The only evidence of coordinated efforts between these agencies and other federal agencies on global freshwater concerns occurred when one subcontracted another. These interactions accounted for a relatively miniscule proportion of overall funds (about \$15 million total).

Of greatest concern, perhaps, is the lack of formalized coordination between all of the government agencies engaged in global water challenges. As a result, the U.S. government has failed to efficiently leverage the immense expertise in various agencies and departments on water issues. Individual agency bureaus are doing meaningful work, but in a largely uncoordinated manner that does not allow better targeting and cooperation.

USAID has made large strides in the past few years to coordinate its water projects internally, but it remains largely isolated even from the Department of State in forming holistic policy approaches, and in forging an established means by which to mobilize the expertise of other government agencies. USAID officially formed the agency-wide Water Team to “support environmentally sound, cross-sectoral and participatory approaches to managing, conserving, and sustainably using freshwater and coastal resources” (USAID 2002). The core staff of the Water Team is located in the Environment Office in the Economic Growth, Agriculture and Trade (EGAT) Bureau. Others across Pillar Bureaus and regional Bureaus are also involved, as are key staff members from missions abroad. Again, the Water Team is only an internal effort and does not expand beyond the boundaries of USAID. In fact, the agency is only allowed to contract another federal agency when there is a demonstrated absence of expertise in nongovernmental sectors.

As the United States faces its own domestic water scarcity and management issues, it will develop new technologies, new capacities, new understandings, and new practices that could be easily exported to help other countries solve

similar problems. There is a great wealth of knowledge in the United States and in the federal agencies that could significantly improve global efforts to improve water availability and management across. For instance, much of the U.S. Bureau of Reclamation's (USBOR) expertise goes underutilized. The USBOR was formed under the Department of the Interior in 1902 and originally tasked with infrastructure development to bring water for irrigation to the many family farms of the west—which the Bureau's work soon made some of the most agriculturally productive in the world. Currently, it is conducting work on energy and cost efficient desalinization through the Water Treatment and Engineering Research (WaTER) project. In addition to the *Water 2025* project and Water Conservation Field Services Program, USBOR has created valuable tools and information that can support future U.S. foreign policy objectives in water and sanitation, and may be especially useful in reducing the potential for future conflict. However, this body of expertise, like many others at USBOR, has been mobilized only ad hoc to meet strategic foreign policy objectives in the area of global water issues. There is no permanent structure linking USAID and USBOR, despite the clear expertise of USBOR in areas of importance to USAID policies.

It may be a simple solution to suggest that a cure for the coordination difficulties between agency redundancies on an important issue would simply be that the United States needs a Department of Water to address mounting domestic and international water issues. In reality, the formation of such a department is unlikely and undesirable. The Department of Energy (DOE) was formed in 1977 in response to the massive energy crisis of the time. Likewise, the Department of Homeland Security (DHS) was formed in 2002, largely in response to the 9/11 attacks. The formations of DOE and DHS have demonstrated that reshuffling agencies is a painful process. Moreover, water is important to the work of almost every US government agency and is integrated into other components that fall squarely under existing core competencies. Therefore, the proper approach to elevate the strategic and operational importance of water in US policy is to invigorate and integrate coordination between agencies. Many studies have suggested approaches that involve the establishment of national councils or other mechanisms to promote inter-agency focus and coordination (Reilly & Babbit 2005, National Council for Science and Environment, 2004). Even a central clearing house that would provide nongovernmental organizations or corporations information on government programs or potential partnership opportunities would be a step in the right direction.

A recent CSIS report on restructuring the Department of Defense noted, "Interagency operations are no longer rare. Yet crises are still managed largely on a case by case basis, with interagency coordination mechanisms reinvented each time. While such *ad hoc* processes are agile, they are neither coherent nor durable. Since there is no reason to believe that today's crisis will be the last, it makes sense to plan for the next one (CSIS 2005)." The post-conflict

involvements on water management in Afghanistan and Iraq make excellent examples of familiar, ongoing crises that have been undertaken more or less as ad hoc interventions in terms of water policy and planning. Almost every government agency has become involved in these issues—but not in any centrally coordinated manner. Policy planning among agencies has improved in each theater with time, but the extent to which cross-agency involvements have been institutionalized is not clear. Relationships are constantly made, broken, and re-established.

From Iraq and Afghanistan to smaller interventions in sub-Saharan Africa, the United States has boldly stood up to massive challenges related to water access and quality in recent years. But the responses have failed to turn successes into practice, and the money that continues to trickle into recipient countries may arrive disaggregated from overarching foreign and country policies. Whether during humanitarian relief missions, or in the course of government business, all too often approaches to country and regional development are taken on spontaneously and without careful consultation with other agencies. The number of agencies—and departments and bureaus within agencies—involved in international activity has increased tremendously in the post-cold war era. Globalization, not surprisingly, has impacted and enticed the U.S. government and its constituent parts. The lingering challenge is for agencies to properly carry out underlying US government policies, and to maximize scales of economy among efforts.

Amidst this new proliferation of US government activity abroad and the importance of water, both the “Medicine, Health, and Safe Water: A Currency for Peace Act of 2005” and the “Water for the Poor Act of 2005” introduced to Congress have recognized the need for better central planning and a high-level mandate for addressing water-related activities. The former act calls on the Secretary of State and the Administrator of the US Agency for International Development (USAID) to formulate—in consultation with foreign and domestic actors in and out of government—a US strategy to meet the foreign policy objective of expanding global access to safe water and sanitation, while encouraging sound water management. The latter bill charges solely the Administrator of USAID with a similar task. But, as described previously, neither bill looks likely to pass Congress, or to receive funding. The language and approach of these bills, however, is appropriate. There is hope that leadership will take these strong beginnings toward sustainable design, appropriate funding and structural reform.

It is not unrealistic to claim that the truly outstanding, cost-effective, forward-looking strategies from the U.S. government are based on multi-agency approaches. An integrated, national strategy for global water issues continues to be an anomaly for one core reason—the absence of a clearly defined mandate

from above. A clash of cultures between government agencies, turf wars, unclear or limiting regulations, and a lack of resources inhibit the dispersed units from coordinated planning and implementation. Nearly every federal agency or research institution has conducted an international water project, but each applies this expertise on a limited, ad-hoc basis. Developing an integrated and cohesive international policy on water will be a major step forward for coordinating efforts, fully utilizing the institutional knowledge of the U.S. government, and achieving many U.S. and foreign policy goals.

Until such time as Congress or the President sees fit to engage the issue of water, progress on the issue will continue to be hard-won. Agencies, bureaus and individuals within them will continue to do good work, engaging this important issue abroad as they have for the past hundred years—and especially the past two decades. NGOs and international organizations will sustain their efforts on water-related issues and will seek to elevate the commitment of recipient governments and communities. But without more concerted US engagement with the issue, from the top levels down, engagement will be costlier, less effective, and less connected to other standing US objectives, including considerations of national security. From upholding important commitments to improving health, education and economic development around the globe and promoting the stability of allies, water plays a critical role in meeting America's objectives to maintain peace and prosperity at home and abroad.

Appendix A: Sample Matrixes for Technology or Policy Approaches

Table 1: UN Millennium Project's policy options for improving access to sanitation

	Density	Existing Service	Supply Side	Demand Side	Possible policy and planning responses
I	Dispersed (rural)	- Little or no improved infrastructure: open defecation	- No institutional home for sanitation -Low priority and limited public investment in rural sanitation	-Poverty -Limited access to credit -Low demand for sanitation improvements	-Social marketing and education -Partnerships with civic organizations -Targeted subsidies and credit programs
II	Dispersed (rural)	Service from dysfunctional private facilities, such as latrines	-No institutional home for sanitation -Limited post-construction support for sanitation -Limited private sector skills for operation and maintenance -Mismatch between levels of service supplied and demanded	-Poverty -Limited access to credit -Low demand for sanitation improvements	-Social marketing and education -Partnerships with civic organizations -Targeted subsidies and credit programs
III	Medium density (small town)	Service from dysfunctional private and public facilities, open defecation	-No institutional home for sanitation -Limited resources available for operation and maintenance -Constraining standards for service improvements	-Limited access to credit -Limited demand for sanitation improvements -Demand captured by private household investment	-Social marketing and education -Partnerships with civic organizations -Regulatory reform (standards, new construction) -Innovative technologies
IV	Medium density (small town)	Service from dysfunctional private facilities	-No institutional home for sanitation -Limited post-construction support for sanitation	-Limited access to credit -Limited demand for sanitation improvements -Demand captured by private household	-Social marketing and education -Partnerships with civic organizations -Regulatory reform (standards, new construction) -Innovative technologies

				investment	
V	High density (urban or peri-urban)	Little or no improved infrastructure: open defecation or use of facilities in other neighborhoods	-No institutional home for sanitation -Growth (newly incorporated areas) -Investment restrictions in unregularized areas -High per capita cost of service -Perceptions of poverty -Constraining standards	-High proportion of rented dwellings -Insecure tenure -Limited access to credit -Poverty -Low demand for sanitation improvements	-Land tenure reform -Social marketing and education -Partnerships with civic organizations -Regulatory reform (standards, new construction) -Innovative technologies
VI	High density (urban or peri-urban)	Service from shared public facilities	-No institutional home for sanitation -High per capita cost of household level supply -Perception of poverty -Constraining standards -Limited funding and incentives for operation and maintenance	-High proportion of rented dwellings -Limited access to credit -Poverty -Low demand for sanitation improvements	-Land tenure reform -Social marketing and education -Partnerships with civic organizations -Regulatory reform (standards, new construction) -Innovative technologies

Source: Lenton, R. and Wright, C. 2004. Interim Report of Task Force 7 on Water and Sanitation. UN Millennium Development Project Task Force on Water and Sanitation.

Table 2: UN Millennium Project's policy options for improving access to water

	Density	Existing Service	Proximate explanations		Possible policy and planning responses
			Supply Side	Demand Side	
I	Dispersed (rural)	- Little or no improved infrastructure: supply from vendors and surface water sources	-Limited public investment in rural water supply. -Perception of poverty. -High per capita cost.	-Poverty -Limited access to credit -Low demand: availability of acceptable alternatives.	-Capacity building and development of collective-action institutions. -Combined agricultural and domestic water projects. Partnerships with civic organizations.

					-Targeted subsidies.
II	Dispersed (rural)	Inadequate supply from shared public facilities, such as bore wells with hand pumps.	-Limited investment in operations, maintenance, and expansion. -Perception of poverty.	-Poverty. -Limited access to credit -Challenges of collective action for operation and maintenance. -Low demand: availability of acceptable alternatives.	-Capacity building and transfer of planning or budgeting authority to local bodies. -Capacity building at national level for long-term community support. -Partnerships with civic organizations. -Targeted subsidies. -Programs to strengthen supply chains.
III	Medium density (small town)	Supply from private household facilities, vendors, and surface water sources.	-Limited public and private investment available for small town water supply. -Policy vacuum.	-Limited access to credit. -Demand captured by private household investment.	-Policy development. -Development of collective-action institutions. -Promotion of small-scale independent providers. -Management innovations (franchising regional utilities). -Targeted subsidy and credit programs.
IV	Medium density (small town)	Service from dysfunctional private facilities	-Inadequate resources and capacity for operation and maintenance of public system. -Policy vacuum.	-Limited potential for use of voice. -Unwillingness to pay higher tariffs for low-quality service. -Higher-income households may exit system.	-Capacity building for operations and maintenance. -Policy development. -Promotion of small-scale independent providers. -Management innovations (franchising regional utilities). -Targeted subsidy and credit programs.
V	High density (urban or	Little or no improved infrastructure: supply	-Growth (newly incorporated	-High proportion of	-Urban development policy

	peri-urban)	from vendors	areas). -Investment restrictions in unregularized areas. -High per capita cost. -Perceptions of poverty. -Constraining standards.	rented dwellings -Insecure tenure -Challenges of collective action.	reform. -Promotion of small-scale independent providers. -Partnerships with civic organizations. -Targeted subsidy and credit programs.
VI	High density (urban or peri-urban)	Supply from shared public facilities	-High per capita cost of supply -Perceptions of poverty. -Constraining standards.	-High proportion of rented dwellings -Challenges of collective action.	-Promotion of small-scale independent providers. -Partnerships with civic organizations to promote dialogue with provider. -Targeted subsidy and credit programs.

Source: Lenton, R. and Wright, C. 2004. Interim Report of Task Force 7 on Water and Sanitation. UN Millennium Development Project Task Force on Water and Sanitation.

Table 4: UN Millennium Project's technology options for improving access to water

Water Source	Abstraction Structure	Abstraction equipment	Required treatment	Applicable situation
Surface water (rivers, streams, lakes)	Dams Direct pumping (lakes, perennial rivers, ponds) for storage in adjacent surface reservoirs (Metropolitan Water Board, London)	Electric pumps	Clarification involving removal of solids and turbidity; disinfection; corrosion prevention treatment (water conditioning)	Large-scale; for large cities or a number of cities and communities
Ground water	Small-diameter wells -Boreholes -Tube wells	Electric/hand pumps	-Mostly disinfection to combat distribution system contamination -Mostly no treatment for household use	-Large-scale systems -Institutions -Domestic and small-scale agricultural uses
Wells	Large-diameter	Hand pumps,	Mostly no	-Village

	wells -Dug wells -Mechanically dug	mostly, also electric	treatment necessary other than disinfection	community use -Household uses
Ground water Spring water	Protected spring box	Springs provided with protective box with open bottom and outlet pipes overflowing continuously leading directly to distribution or to storage tanks	No treatment normally provided because such spring water is normally potable	Rural sites
Rainwater	-Roof catchments into domestic tanks -Ground surface catchments into storage ponds (as in Bermuda)	-None -Simple mechanical pumps	Non or simple disinfection	-Islands with no surface or groundwater sources -Small rural communities -Households
Saline water	Pumping from ground or surface, such as seas	Electric pumps	Desalination, including reverse osmosis	Water-scarce areas with access to sea or saline water sources

Source: Lenton, R. and Wright, C. 2004. Interim Report of Task Force 7 on Water and Sanitation. UN Millennium Development Project Task Force on Water and Sanitation.

Table 6: UN Millennium Project's technology options for improving access to sanitation

Type of System	Purpose	Technological options	Conditions suited for use
On-site sanitation	Excreta disposal	Simple, unventilated, double-pit toilet: used on pit at a time while the other rests until fully decomposed contents are safe to use on land	Low water usage; poor soil permeability; low water table; low to medium housing density
		Pour-flush toilet with twin soakaway pits reused and rested alternative; intended for emptying	Medium water use; ablution water; good soil permeability; low water table; low to medium housing density
		Pour-flush toilet plus septic tank with twin-pit soakaway pits, reused and rested alternatively	High water usage; poor soil permeability; high housing density; high water table
		Compost toilets (Ecosan toilet)	Low water usage
	Wastewater disposal	Separate twin-pit soakaway system for sullage disposal	Medium-high water usage; on-site sanitation to dispose of excreta
Off-site sanitation	Wastewater conveyance	Low-volume flush water closets with simplified sewerage or with small diameter, shallow-depth, and flat-gradient sewers	High water usage; poor soil permeability; high housing density; high water table; on-site sanitation to dispose of excreta
	Primary treatment	Pour-flush toilets or low-volume flush water closets with Imhoff Tank and sludge-drying beds	Small communities and medium towns with high water usage
		Low-volume flush toilets with conventional primary treatment, screening, grit removal and sedimentation	For medium to large towns and megacities
	Secondary treatment	Trickling filters with sludge digesters or co-composting of sludge with garbage	Long-term solution to wastewater disposal in medium to large cities
	Alternative treatment options	Constructed wetlands In-stream wetlands and waste stabilization ponds	Areas where odor risk is low

Source: Lenton, R. and Wright, C. 2004. Interim Report of Task Force 7 on Water and Sanitation. UN Millennium Development Project Task Force on Water and Sanitation.

See also CSD. 2005. "User-Friendly Matrix of the Chair's IPM Summary." UN Economic and Social Council, New York.

Appendix B: Current U.S. Government International Water Activities

USG Agencies Currently Engaged in International Water-Related Activity	
<i>Agency</i>	<i>Types of Current and Historical International Activity</i>
U.S. Agency for International Development (USAID)	Water supply; integrated water resource management; technical assistance; financial assistance programs for infrastructure improvements; local capacity building and education.
Department of State (DOS)	Lead agency in US foreign policy and negotiations; provides funding for watershed management and improvement of water supply systems and sanitation.
Department of Defense (DOD)	Disaster relief operations, including desalination; water management in global areas of operation.
Peace Corps (PC)	Hygiene and sanitation education; improves water quality through sanitation efforts in 14 countries.
Department of Energy (DOE)	Training and public awareness; renewable energies technology research; capacity building; water quality monitoring; energy efficiency in water delivery.
Department of Commerce, National Oceanic and Atmospheric Agency (NOAA)	Cross-sectoral watershed management; marine and coastal area improvements; marine ecosystem-based management; satellite imagery and data exchange partnerships.
Department of Commerce (DOC)	Trade promotion and facilitation for U.S. water businesses; international market research; improve U.S. competitiveness in the international water market.

Department of Housing and Urban Development (HUD)	Refurbish and construct stable water systems; water, sanitation and solid waste management; disaster reconstruction assistance.
US Army Corps of Engineers (USACE)	Share best practices learned; water infrastructure development; water resource management and development; flood control; soil and groundwater remediation; wastewater treatment operations; capacity building
Environmental Protection Agency (EPA)	Public education; water monitoring; transboundary water issues.
Department of Agriculture (USDA)	Ecosystem and conservation training; soil conservation; watershed management; soil protection; flood prevention.
Federal Emergency Management Agency (FEMA)	Technical assistance and technology exchange to support emergency management during natural disasters
National Science Foundation (NSF)	Financing for research initiatives and scientific exchanges.
The National Academies (NA)	Public education; funding for practical technology applications.
Overseas Private Investment Corporation (OPIC)	Provide funding mechanisms for small and medium water-related enterprises.
Export-Import Bank (EX-IM)	Finances U.S. exports that maintain American jobs, including water and sanitation related infrastructure.
National Science and Technology Council (NSTC)	Provides overall research guidance for government scientific agencies.
Dept. of the Interior, Geological Survey (USGS)	Training; hydrological surveys; water resource mapping.

Dept. of the Interior, Bureau of Reclamation (USBR)	Technology exchange, training and technical assistance in water resource management and environmental recovery.
Dept. of the Interior, Fish and Wildlife Service (FWS)	Research, public awareness, professional training, resource management; environmental education; enhance local institutional capabilities; water management and conservation; protection of freshwater and coastal wetlands.
Dept. of the Interior, National Park Service (NPS)	Technical assistance and exchange in protection of natural habitats and ecosystems.

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